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RAS WALLAH (STATIC)

PRELIMS 2026

SCIENCE & TECHNOLOGY

QUICK AND COMPREHENSIVE REVISION SERIES FOR RAS EXAM

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1 Basics of Everyday Science

MECHANICS

Scalar and Vector Quantities

- **Scalar:** Has only magnitude (size).
  - **Examples:** Distance (5 m), Speed (60 km/h), Mass (10 kg).
- **Vector:** Has both magnitude and direction.
  - **Examples:** Displacement (5 m east), Velocity (60 km/h north), Force (10 N downward).

Some Key Terms

Velocity

- Velocity is a vector quantity that represents the rate of change of an object's position with respect to time in a specific direction. It tells both how fast an object is moving (speed) and in which direction. SI Unit of Velocity is m/s.
- $v = \Delta s/\Delta t$, Where: v = velocity, Δs = displacement (change in position), Δt = time interval

Acceleration

- It is defined as the rate of change of velocity with respect to time. SI unit of acceleration is meter per second square.
- $a = \Delta v/\Delta t$, where: a = acceleration, Δv = change in velocity, Δt = time interval

Momentum

- Momentum is a vector quantity that represents the product of an object's mass and its velocity. SI unit for momentum is the kilogram-meter per second.
- It indicates how much motion an object possesses and is given by the equation:
  - **P = mv,** where P = momentum, v = velocity and m = mass
- **Law of Conservation of Momentum:** According to the law of conservation of momentum, the total momentum of an isolated system remains constant if no external forces act on it. **Ex-** To escape a frictionless frozen lake with only a bag, a person can apply the Law of Conservation of Momentum by throwing the bag in the direction opposite to the shore. Since the total momentum of the "man + bag" system must remain zero in the absence of external horizontal forces, the momentum gained by the bag is balanced by an equal and opposite momentum acquired by the person, granting them the velocity needed to slide to safety.

Force and Newton's Laws of Motion

Force

- Force is a push or pull exerted on an object that causes it to change its velocity (accelerate) or shape.
- It is a vector quantity and is measured in Newtons (N).

Newton's First Law (Law of Inertia)

- A body remains in a state of rest or uniform motion in a straight line unless acted upon by an external force.
- **Example:** A book on a table stays still until you push it.

Newton's Second Law (Law of Acceleration)

- The acceleration of an object is directly proportional to the net force acting on it and inversely proportional to its mass. This means to give equal acceleration to two objects, one needs to apply greater force on the heavier object.
- **Equation: F = ma**, where: m is mass, and a is acceleration.
  - This equation can be expressed in terms of momentum also. **$F = \Delta P/\Delta t$ meaning Force is rate of change of momentum.**
- **Example:** A car accelerates faster when pushed with greater force.

Newton's Third Law (Action-Reaction)

- For every action, there is an equal and opposite reaction.
- **Example:** A rocket moves upward by expelling gases downward. The gases being forced downward push the rocket upwards as explained by Third Law.

Friction

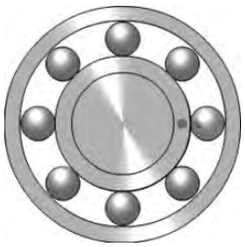
Friction is a force that opposes the relative motion between two surfaces in contact. It arises due to the interactions at the microscopic level of the surfaces involved. SI unit for friction is newton (N).

Types of Friction

1. **Static Friction:**
   - The force that must be overcome to start moving an object at rest.
2. **Kinetic (Sliding) Friction**
   - The force that opposes the motion of two surfaces sliding against each other.

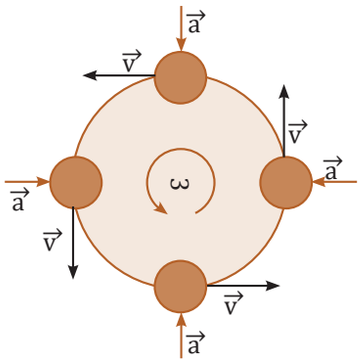
3. Rolling Friction

- The resistance encountered when an object rolls over a surface. Here the surface area of contact is reduced and thus movement becomes easy.



- **Example: Ball bearing.** The balls roll between the inner and outer ring. Contact surface is limited to a single point at both surfaces thus greatly reducing the friction and making the motion smooth.

Circular Motion and Centrifugal Force



Circular motion is the movement of an object along a circular path. It can be **uniform** (constant speed) or **non-uniform** (changing speed). A circular motion is always accelerated as direction of speed changes at every instant.

Imagine rotating a stone tied to a string in a horizontal circle. You will have to apply a force on the string towards the centre of the circle at every instant so that it remains in the circle.

v shows direction of velocity, **a** shows centripetal acceleration and also the direction of force applied by string on the stone.

ω is angular velocity and is given by angle covered per unit time in the circular motion.

1. Centripetal Acceleration:

- Acceleration directed toward the centre of the circle, calculated as: v = velocity, r = radius

$$a_c = \frac{v^2}{r}$$

2. Centripetal Force = mass × Centripetal acceleration

- The net force required to keep an object in circular motion:

$$F_c = \frac{mv^2}{r}$$

Centrifugal Force

Definition: Centrifugal force is an apparent outward force felt by an object moving in a circle, caused by inertia.It is directed away from the centre of the circle

Applications

1. **Skimming of Milk:** Cream is less dense than skimmed milk, the effect of centrifugal force causes the denser milk to move outward toward the container walls. Consequently, the lighter cream is displaced toward the center—that is, toward the axis of rotation—from where it can be easily separated (or collected).
2. **Vehicles on Curved Roads:** Centripetal force keeps cars on the road; insufficient friction can lead to skidding.
3. **Satellites:** Remain in orbit due to centripetal force from gravity.
4. **Shape of Earth:** Oblate spheroid shape is due to greater centrifugal force near the equator.
5. **Centrifuges:** Separate substances by spinning them rapidly, utilising centrifugal force.
6. **Tides:** Combined effect of gravitational pull of Sun, Moon and centrifugal force due to rotation of earth on its axis.

Pressure

Definition: Pressure is the force exerted per unit area:

$$P = F/A$$

where P is pressure, F is force, and A is the area. It is measured in Pascals (Pa), Atmospheric pressure(atm) etc.

1 Pa = 1 Newton/metre square, 1 atm = 1.013 × 10^5 Pa.

Factors Affecting Pressure

1. Force- More force → More pressure
2. Area- Smaller area → More pressure (inverse relation)
3. Depth (in liquids)- Pressure increases with depth
4. Density- Denser fluid exerts more pressure

Flow of Fluids

- **Pressure Difference:** Fluids flow from areas of higher pressure to areas of lower pressure. This principle governs many systems, such as water supply in pipes and blood circulation in the body.

Pressure and Altitude

- **Pressure Variation:** Atmospheric pressure decreases with altitude because the density of air decreases as altitude increases. This phenomenon explains why higher altitudes have lower oxygen availability, impacting human physiology and performance.
- **Cooking of Rice at Higher Altitude**
  - **Cooking Challenges:** At higher altitudes, the atmospheric pressure is lower, resulting in a lower boiling point for water (below 100°C). This means rice and other foods **take longer to cook,** as water does not reach as high a temperature.

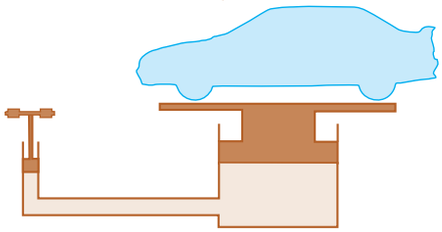
Boiling Point of Water and Increased Pressure

- The boiling point of water **increases with an increase in pressure**. At higher pressures, water molecules require more energy (higher temperature) to escape into the vapour phase, meaning **water boils at a temperature higher than 100°C.**

Cooking of Rice in Pressure Cookers

- **Pressure Cookers:** Pressure cookers **raise the boiling point of water** due to increased pressure inside the cooker. This allows rice and other foods to cook faster, as the **temperature inside the cooker can exceed 100°C.**

Application of Pressure in Hydraulic Lifts



- **Hydraulic Lifts:** These devices use the principles of fluid pressure to lift heavy objects. By applying a small force on a piston, a large force is generated through a fluid, allowing for lifting capabilities in hydraulic systems, such as car lifts and elevators.

Practical Applications of Pressure

- **Straw Use:** When you suck on a straw, you create a **low-pressure area inside the straw.** The higher atmospheric pressure outside pushes the liquid up into the straw, allowing you to drink.

Land and Sea Breezes

- **Breezes Formation:**
  - **Land Breeze:** At night, land cools faster than water, creating higher pressure over land and lower pressure over the sea. The wind blows from the land to the sea.
  - **Sea Breeze:** During the day, the land heats up faster than the sea, causing lower pressure over land and higher pressure over the sea. The wind blows from the sea to the land.

Cloud Formation and Rainfall

- **Cloud Formation:** Clouds form in areas of low pressure when warm, moist air rises and cools, reducing its capacity to hold moisture. As the air cools, water vapour condenses into tiny droplets, forming clouds.
- **Rainfall:** When cloud droplets coalesce and grow heavy enough, they fall as precipitation (rain). This process is influenced by atmospheric pressure variations.

Desert Formation

- **Desert Conditions:** Deserts often form in areas of high pressure, where dry air descends, inhibiting cloud formation and precipitation. This leads to arid conditions and limited rainfall.

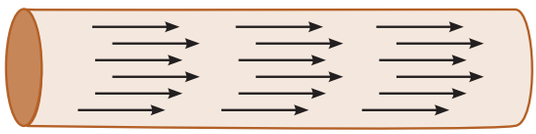
Bar, Pascal (Pa), Torr, and Atmosphere (atm) are all units used to measure pressure. **(RAS 2024)**

FLUID DYNAMICS

Laminar Flow:

- In laminar flow, the fluid moves in parallel layers without mixing. Velocity at any point in the fluid remains constant over time, and the flow lines are smooth and orderly. This type of flow occurs when the Reynolds number (a dimensionless number that indicates flow type) is low.
- **Example: Blood flowing through narrow capillaries** follows laminar flow, where each layer of blood moves smoothly past the others.

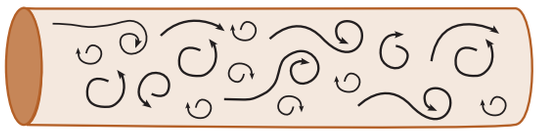
Laminar Flow



Turbulent Flow:

- Turbulent flow is chaotic, with irregular velocity at different points in the fluid. Eddies and vortices form, and the flow becomes highly mixed. Turbulent flow occurs when the Reynolds number is high, indicating that inertial forces dominate over viscous forces.
- **Example:** Water rushing through a large pipe or river exhibits turbulence, with swirling currents and unpredictable flow paths.

Turbulent Flow



Diffusion

- Diffusion is the random movement of particles (like atoms or molecules) due to thermal energy. Over time, particles spread out from regions of high concentration to low concentration until equilibrium is reached.
- **Example:** The **diffusion of oxygen into red blood cells** across the alveolar membrane in the lungs, where the concentration of oxygen is higher in the alveoli than in the blood.

Osmosis

- Osmosis is a special case of diffusion involving the movement of water across a semipermeable membrane. Water moves from a region of low solute concentration to one of high solute concentration to balance the concentration on both sides of the membrane. It is driven by osmotic pressure.

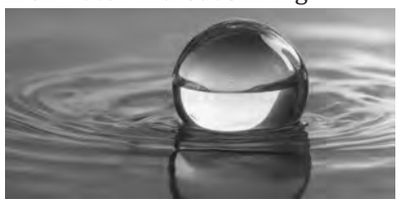
- **Example:** Plant roots absorb water from the soil through osmosis, as the concentration of water is higher in the soil than in the root cells.

Dialysis

- Dialysis involves the selective movement of solute particles through a semipermeable membrane based on size or concentration. It uses diffusion to remove unwanted particles (such as toxins or waste products) from a solution, allowing only small molecules to pass through the membrane.
- In **kidney dialysis**, a machine uses a semipermeable membrane to remove waste products from the blood of patients with kidney failure.

Surface Tension

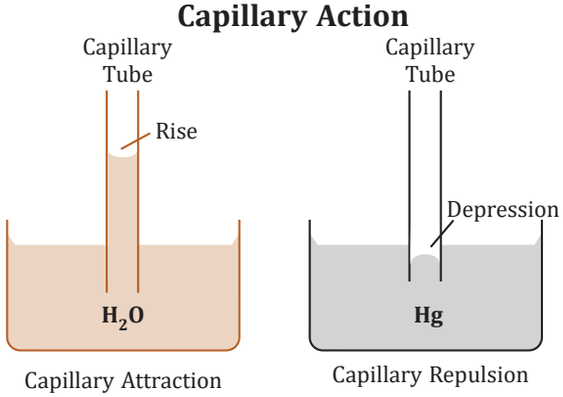
- Surface tension arises because molecules at the surface of a liquid experience a **net inward force due to cohesion** (attractive forces between similar molecules). This creates a "skin" on the liquid's surface, minimising its surface area.
- **Example:** Water droplets on a leaf **bead up** due to surface tension, and small insects like water striders can walk on water without sinking.



- Water droplets take a spherical shape because surface tension pulls the water molecules inward, reducing the surface area as much as possible. **A sphere has the smallest surface area for a given volume, so it's the most efficient shape.**

Capillarity (Capillary Action)

- **Physics Explanation:** Capillarity occurs when a liquid spontaneously rises or falls in a narrow tube due to adhesive forces between the liquid and the tube's walls and cohesive forces within the liquid itself.



- **Shape of Meniscus:** concave up, convex up or flat depends upon whether cohesive forces among molecules of liquid dominate over adhesive force between capillary tube and molecules of the liquid.
  - Cohesive > Adhesive = convex up, Mercury, liquid level falls as shown.
  - Adhesive > Cohesive = concave up, Water, liquid level rises in the capillary tube as shown.
- **Example:** Capillary action helps water travel up the xylem in plants, allowing water to reach the top leaves.

HEAT AND THERMODYNAMICS

Temperature and Heat

- **Temperature:**
  - **Definition:** Temperature measures the average kinetic energy of particles in a substance, determining how hot or cold something is.
  - **Units:** Measured in Celsius (°C), Fahrenheit (°F), or Kelvin (K). Kelvin is the SI unit, directly related to absolute temperature.
- **Heat vs. Temperature:**
  - **Heat:** The energy transferred due to temperature difference, measured in joules (J).
  - **Temperature:** A measure of the average motion of particles in a substance.
  - **Difference:** Heat depends on mass and temperature difference, whereas temperature is an intensive property (does not depend on the amount of substance).

Heat Transfer and Conductivity

- **Good and Bad Conductors of Heat:**
  - **Good Conductors:** Materials like metals that quickly transfer heat, due to free electrons. Ex- Silver, Copper, Aluminum, Iron etc.
  - **Bad Conductors (insulators):** Materials like wood or rubber, which restrict heat flow, making them useful for insulation. Ex- Cork, Wool, Glass, Paper, Thermocol etc.
- **Modes of Heat Transfer:**
  - **Conduction:** Transfer of heat through direct contact (e.g., metal rod in a flame).
  - **Convection:** Heat transfer through fluid motion (e.g., boiling water).
  - **Radiation:** Heat transfer without a medium, through electromagnetic waves (e.g., heat from the sun).

Specific Heat Capacity and Its Applications

- **Specific Heat Capacity:**
  - **Definition:** The amount of heat needed to raise the temperature of 1 kg of a substance by 1°C.
    - Substances with high specific heat take longer to heat up or cool down.
    - Substances with low specific heat heat up and cool down quickly.

- **High Specific Heat of Water:** Water requires more energy to change its temperature, which stabilises Earth's climate.

- **Applications:**
  - **Oceans and Climate:** Oceans store large amounts of heat due to water's high specific heat. During winters, oceans release this heat slowly, keeping coastal regions warmer.
- **Relation Between Surface Area and Rate of Cooling:**
  - **Newton's Law of Cooling:** The rate of heat loss is proportional to surface area and the temperature difference between the object and its surroundings. Larger surface areas result in faster cooling. Larger temperature difference between object and surrounding leads to larger rate of cooling.
  - **Example:** A 60 degree celsius iron rod cools faster in a room at 5 degree celsius than in a room at 15 degree celsius.

Water: Phases and Special Properties

- **Phases of Water:**
  - Water exists in three phases: Solid (ice), liquid, and gas (vapour).
- **Latent Heat:**
  - **Definition:** Energy required for a substance to change its phase (e.g., from ice to water) without temperature change.
  - **Significance:** Latent heat explains why ice absorbs large amounts of energy when melting, stabilising temperatures.
- **Water's Maximum Density and Frozen Lakes:**
  - **Density Anomaly:** Water is **densest at 4°C**. This causes lakes to freeze on the surface first while the denser, warmer water stays below, allowing aquatic life to survive.

Black Body Radiation

Black Body: It is a perfect absorber and emitter of all wavelengths of radiation. A black body emits radiation based on its temperature. This principle is fundamental to understanding the heat emission of stars and planets.

Greenhouse Effect

- **Definition:** The greenhouse effect is the trapping of the sun's heat by Earth's atmosphere, through gases like CO_2, water vapour, and methane.

  It keeps Earth warm enough for life by preventing excessive heat from escaping into space.
- **Cloudy Nights and Greenhouse Effect:** Clouds act as a thermal blanket, trapping heat during the night, which prevents rapid cooling. This is an extension of the greenhouse effect.

Cryogenics and its Application

Cryogenics is the study of materials at very low temperatures such as below -150°C, revealing unique properties like superconductivity.

Key Applications

- **Cryogenic Refrigeration:** Used for freezing biological samples (e.g., liquid nitrogen).
- **Superconducting Materials:** Critical in MRI machines and particle accelerators (e.g., Large Hadron Collider).
- **Space Exploration:** Utilizes cryogenic fuels (liquid hydrogen/oxygen) for rocket propulsion.
- **Medical Applications:** Cryosurgery employs liquid nitrogen to remove tumors.
- **Cryopreservation:** Cells and tissues stored at ultra-low temperatures for fertility treatments.
- **Scientific Research:** Studying materials in condensed matter physics and quantum mechanics.
- **Industrial Applications:** Natural gas liquefaction for efficient transport.

OPTICS AND SOUND

Optics

Light: Light is radiant energy that travels in waves. Scientists have long debated its nature, and now understand that it behaves both like waves and particles. In vacuum its speed is 3×10^8 m/s (fastest in nature).

Reflection

- **Definition:** The bouncing back of light when it hits a smooth surface, governed by the laws of reflection.
- **Laws of Reflection:**
  - The angle of incidence equals the angle of reflection.
  - The incident ray, reflected ray, and normal to the surface lie in the same plane.
- **Practical Applications of Reflection**
  - **Mirrors:** Used for grooming, safety, and optical devices.
  - **Solar Cookers:** Employ parabolic mirrors to concentrate sunlight for efficient cooking.
  - **Periscopes and Optical Instruments:** Utilize reflection principles for viewing from concealed positions.

Refraction

- **Definition:** The bending of light as it passes from one medium to another,it is described by Snell's Law.
- **Core Physics Principle:** The change in speed of light in different media results in refraction.

- The refractive index (n) of a medium is defined as the ratio of the speed of light in a vacuum (c) to the speed of light in that medium (v):
  - $n = c/v$
- **Convergence**
  - **Denser Medium:** Light slows down and bends towards the normal when entering a denser medium (e.g., air to glass). This causes parallel rays to converge through a convex lens.
  - **Applications:** Used in cameras, microscopes, and corrective lenses for hyperopia (farsightedness). **(RAS 2023)**
- **Divergence**
  - **Less Dense Medium:** Light speeds up and bends away from the normal when exiting a denser medium. This causes rays to diverge through a concave lens.
  - **Applications:** Used in glasses for myopia (nearsightedness) and in expanding laser beams. **(RAS 2023)**
- **Practical Applications and Observations**
  - **Lenses in Glasses and Cameras:** Correct vision and focus images, employing advances in optics and material science.
  - **Contact Lenses:** Made from hydrophilic materials that maintain moisture, improving comfort and clarity.
  - **Red Sky at Dawn and Dusk:** The scattering of shorter wavelengths of light during sunrise and sunset leads to vibrant colors in the sky, demonstrating the principles of light refraction and scattering.

Total Internal Reflection (TIR)

- **Definition:** Occurs when light travelling from a denser to a less dense medium is completely reflected at a boundary above a critical angle.
- Critical Angle is the maximum angle at which light can strike the boundary and still refract, beyond this, light is totally internally reflected.
- **Practical Applications**
  - **Optical Fibers:** Use TIR to transmit data over long distances with minimal loss, revolutionising telecommunications and internet technology.
  - **Diamond Sparkle:** The brilliance of diamonds is enhanced by TIR, causing them to reflect light in multiple directions.
  - **Mirage:** A mirage is a naturally occurring optical phenomenon caused by the combined effect of continuous atmospheric refraction and Total Internal Reflection (TIR). As light travels through successive layers of air with progressively lower density near the hot ground, it undergoes continuous refraction, bending away from the normal. In the lowermost hot air layer, when the angle of incidence exceeds the critical angle, Total Internal Reflection occurs, creating the illusion of water or an inverted image.

Dispersion

- **Definition:** The separation of white light into its component colours when passing through a prism due to varying refractive indices.
- Dispersion occurs because white light is a mixture of seven colors, each with a unique wavelength that refracts at a different angle upon entering a prism. Violet light, possessing the shortest wavelength, bends the most, while red light, with the longest wavelength, bends the least; this differential bending causes the light to separate into its constituent colors, creating a visible spectrum.
- **Practical Applications**
  - **Spectroscopy:** Analyses light spectra from celestial bodies, crucial in astrophysics for understanding the universe's composition.
  - **Rainbow Formation:** A natural display resulting from light dispersion, refraction, and reflection in raindrops.

Mirrors

- **Definition:** Reflective surfaces that form images, classified into plane, concave, and convex mirrors.
  - Used in telescopes to gather and focus light for enhanced astronomical observations.
  - **Convex Mirrors:** Provide a wider field of view in safety applications, improving traffic safety and surveillance.

Lenses

- **Definition:** Transparent objects that refract light to converge (convex) or diverge (concave) rays.
- **Practical Applications**
  - **Microscopes and Telescopes:** Employ combinations of lenses to magnify small or distant objects, advancing biological and astronomical research.
  - **Bionic Eyes:** Utilise advanced optics to restore vision, integrating biomedical engineering and electronic sensors.
    - Monash University in Australia has unveiled the 'Gennaris Bionic Vision System', a pioneering bionic eye designed to restore vision by bypassing damaged optic nerves and sending signals directly to the brain. Following promising animal studies, human clinical trials are set to commence in Melbourne.

Prisms

- **Definition:** Geometric optical devices that refract light, often leading to dispersion.
- **Practical Applications**

- **Prism Binoculars:** Use prisms to shorten optical paths while maintaining clarity, essential in outdoor and military applications.

Brownian Motion

- **Definition:** Random motion of microscopic particles suspended in a fluid, resulting from collisions with molecules in the medium.
- **Practical Applications**
  - **Nanotechnology:** Understanding Brownian motion is crucial in developing nanomaterials and drug delivery systems, optimising their movement and interaction with cells.

Doppler Effect

- **Definition:** The change in frequency or wavelength of a wave in relation to an observer moving relative to the source of the wave.
- **Practical Applications/Observations**
  - **Astronomy:** Used to measure the velocity of stars and galaxies, determining their movement and helping to reveal the expansion of the universe. The redshift indicates objects moving away, while blueshift indicates objects moving closer.
  - **Medical Imaging:** Employed in Doppler ultrasound to assess blood flow, providing critical data for cardiovascular health diagnostics.
  - **Sound of a Passing Train:** The frequency of the sound waves increases as the train approaches (higher pitch) and decreases as it moves away (lower pitch).
  - Police radar guns use the Doppler Effect to measure vehicle speed.
  - Astronomers observe redshift in light from galaxies moving away from Earth.
  - Blueshift occurs when a star or galaxy moves toward Earth.
  - Doppler ultrasound measures blood flow and heartbeat in medical scans.
  - Weather radars detect wind and storm movement by frequency change.
  - Submarines use sonar Doppler shift to determine relative motion of targets.

Human Eye and Vision

- **Structure:** Light enters through the cornea, refracts through the lens, and forms an image on the retina, which is converted into signals for the brain.
- **Practical Applications**
  - **Optical Technologies:** Lens design for vision correction is informed by understanding optical physics, enhancing safety and quality of life.
  - **Bionic Eye Technology:** Merges optics and electronics, using sensors to convert light into electrical signals, aiming to restore vision in individuals with retinal diseases.

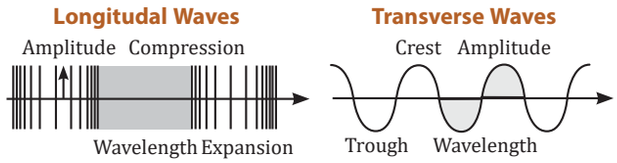
Sound

Definition: Sound is a form of mechanical energy that travels in waves through different mediums such as air, water, and solids.

Comparison to Light

- **Nature:** Sound is a longitudinal wave, while light is a transverse wave.

Types of Waves



- **Medium Requirement:** Sound requires a medium to travel, whereas light can travel through vacuum.

Speed of Sound in Various Mediums

- **Air:** Approximately 343 metres per second.
- **Water:** About 1,480 metres per second.
- **Solids (e.g., steel):** Approximately 5,960 metres per second.

Reason for Difference in Speed

The speed of sound varies based on the medium's density and elasticity. Sound travels faster in solids than in liquids and faster in liquids than in gases because particles in solids are closer together and can transmit vibrations more quickly.

Unit of Sound

The loudness of sound is measured in **decibels (dB).** The frequency of sound is measured in Hertz(Hz).

Range of Audible Sound

Humans can typically hear sounds in the range of **20 Hz to 20,000 Hz (20 kHz).**

Hypersonic and Mach Definitions

- **Hypersonic:** Refers to speeds greater than **Mach 5** (five times the speed of sound).
- **Mach Number:** A dimensionless unit representing the ratio of the speed of an object to the speed of sound in the surrounding medium.

Sonic Boom

A sonic boom occurs when an object travels faster than the speed of sound, creating shock waves that produce a loud sound, similar to an explosion.

Organ Pipes and Principle

Organ pipes produce sound through the vibration of air columns within a hollow tube. The sound is generated by the movement of air, which creates standing waves, leading to the production of musical notes. **Example:** Flute,Saxophone etc.

Doppler Effect

The Doppler Effect is the change in frequency (or pitch) of sound as the source moves relative to an observer. For example, when an ambulance approaches, the siren sounds higher in pitch, and as it moves away, the pitch lowers.

Applications of Sound in Modern Science and Technology

1. **Medical Imaging:** Ultrasound uses high-frequency sound waves to create images of internal organs.
2. **Navigation:** Sonar (Sound Navigation and Ranging) employs sound propagation to navigate and detect objects underwater.
3. **Acoustic Levitation:** Using sound waves to lift small particles or droplets in the air without physical contact.
4. **Audio Technology:** Speakers and microphones convert electrical signals into sound and vice versa, essential for communication devices.

Stethoscope – Principle of Multiple Reflection of Sound (RAS 2021)

- A stethoscope is a medical instrument used to listen to internal body sounds such as the heartbeat, lung sounds, and blood flow. It works on the principle of multiple reflection of sound.
- When the diaphragm of the stethoscope is placed on the patient's body, the sound vibrations produced by the heart and lungs are collected and transmitted through the hollow tube. As the sound travels through the tube, it undergoes multiple reflections from the inner walls, allowing it to reach the doctor's ears with greater intensity and clarity.
- The chest piece and tube help amplify weak body sounds, making them easier to hear. A cardiology stethoscope contains a diaphragm, bell, tubing, and earpieces, which together facilitate efficient sound transmission.

ELECTRICITY AND MAGNETISM

Basic Concepts

- **Electric Charge**
  - **Definition:** A property of matter that causes it to experience a force in an electromagnetic field. There are two types of charges: positive and negative. SI Unit of electric charge is Coulomb (C).
  - **Applications:** Used in capacitors to store energy, crucial for electronic circuits and devices.
- **Electric Current**
  - **Definition:** The flow of electric charge through a conductor, measured in amperes (A). It can be direct (DC) or alternating (AC). SI Unit of electric current is Ampere.
  - **Applications:** Powers household appliances, electronic devices, and industrial machinery. DC is used in batteries, while AC is used for home electricity supply.
- **Voltage (Electric Potential)**
  - **Definition:** The difference in electric potential between two points in a circuit, measured in volts (V).
  - **Applications:** Essential for the operation of electrical systems; higher voltage allows for efficient power transmission over long distances, reducing energy loss.
- **Resistance**
  - **Definition:** Opposition to the flow of electric current, measured in ohms (Ω). It varies with material, length, and cross-section.
  - **Applications:** Used in heating elements (like toasters), light bulbs, and electronic devices where controlled resistance is needed.
- **Ohm's Law**
  - **Definition:** States that current (I) is directly proportional to voltage (V) and inversely proportional to resistance (R).
  - **Equation:** $V = I \times R$
  - **Applications:** Fundamental in designing circuits, ensuring components operate within safe limits.
- **Series and Parallel Circuits**

  Definition:
  - **Series Circuit:** Components connected end-to-end; same current flows through all.
  - **Parallel Circuit:** Components connected across common points; same voltage across all.

  Applications: Series circuits are used in string lights, while parallel circuits are used in home wiring to ensure appliances can operate independently.
- **Magnetic Field**
  - **Definition:** A region around a magnetic material or moving electric charge where magnetic forces are experienced, measured in Tesla (T).
  - **Natural Phenomenon:** Earth's magnetic field protects the planet from solar radiation and helps animals navigate during migration.
- **Electromagnetism**
  - **Definition:** The interaction between electric charges and magnetic fields; changing electric fields generate magnetic fields and vice versa.
  - **Applications:** Used in electric motors, generators, and transformers. Electromagnets are essential in various applications, including maglev trains and MRI machines.
- **Faraday's Law of Electromagnetic Induction**
  - **Definition:** A change in magnetic flux through a circuit induces electromotive force (EMF).

- **Applications:** Utilised in electric generators, where mechanical energy is converted into electrical energy. Also crucial in wireless charging technology.

❖ **Applications in Modern Science and Technology**

- **Electric Motors:** Convert electrical energy into mechanical energy, found in electric vehicles and household appliances.
- **Transformers:** Adjust voltage levels for efficient power transmission, minimising energy loss over long distances.
- **Magnetic Resonance Imaging (MRI):** Utilises strong magnetic fields to create detailed images of tissues, revolutionising medical diagnostics.
- **Wireless Communication:** Electromagnetic waves are fundamental in technologies like Wi-Fi, Bluetooth, and mobile communications.

❖ **Natural Phenomena**

- **Auroras:** Caused by charged particles from the sun interacting with Earth's magnetic field, creating stunning displays of light in polar regions.
- **Lightning:** A natural discharge of electricity that occurs due to differences in electrical charge between clouds and the ground.

CHEMISTRY IN EVERYDAY LIFE

Chemistry touches every facet of life, from medicines and foods to cleaning agents and cosmetics. This chapter delves into the role of chemistry in our daily lives, focusing on **medicines**, **food materials**, **cleansing agents**, and important chemicals in the news for various reasons.

MEDICINES AND DRUGS

Medicines are chemical compounds that interact with biological systems to treat ailments. Incorrect usage can lead to toxic effects. The field of **chemotherapy** refers to the use of chemicals in therapeutic treatment. This section also includes recent drug discoveries and essential medical chemicals.

Classification of Drugs Classification based on:

❖ **Pharmacological effect**: Examples include **paracetamol** (antipyretic), **ibuprofen** (analgesic), and **chloroquine** (antimalarial). Newer drugs like **Remdesivir** and **Paxlovid** (for COVID-19) are also gaining attention.

❖ **Drug action**: Drugs like **antiviral medications** (such as **Favipiravir**) act on viral replication, while **antihistamines** (e.g., **Loratadine** and **Cetirizine**) inhibit the action of histamine in allergic reactions.

❖ **Chemical Structure**: Drugs such as **sulphonamides** (e.g., **sulfadiazine**) are classified based on structural similarities, making it easier to predict their activity.

❖ **Molecular Targets**: In addition to proteins and nucleic acids, newer drug developments target **enzymes** (e.g., **Protease inhibitors** used in HIV treatment) and **receptors** (like **ACE2** in COVID-19).

Drug-Target Interaction

❖ **Enzymes as drug targets**: Enzyme inhibitors, such as **Nevirapine** (HIV), and newer drugs like **Nirmatrelvir** (a protease inhibitor for COVID-19), show how drugs interact with active sites.

❖ **Receptors as drug targets**: **Opioid receptors** targeted by drugs like **Naloxone** (used in opioid overdose treatment) are crucial in managing pain and addiction.

Recent Developments in Medicines

❖ **Monoclonal Antibodies**: Drugs like **Tocilizumab** and **Regeneron's antibody cocktail** have been highlighted for treating COVID-19.

❖ **Immunotherapy**: Drugs such as **Pembrolizumab** (for cancer) have gained attention for harnessing the body's immune system.

THERAPEUTIC ACTION OF DRUGS

This section expands on specific drugs used to manage medical conditions, incorporating modern breakthroughs and widely used treatments.

Antacids

Along with **cimetidine** and **ranitidine**, newer antacids like **esomeprazole** and **pantoprazole** are popular proton pump inhibitors (PPIs) that effectively reduce stomach acid.

Antihistamines

In addition to **brompheniramine** and **terfenadine**, modern antihistamines like **Fexofenadine** (Allegra) are widely used due to fewer sedative side effects.

Neurologically Active Drugs

❖ **Tranquilizers**: New drugs like **Clonazepam** and **Alprazolam** are commonly prescribed to manage anxiety and panic disorders.

❖ **Analgesics**: **Oxycodone** and **Fentanyl**, though effective for pain relief, have gained attention due to their role in the opioid crisis.

Antimicrobials

❖ **Antibiotics**: Beyond **penicillin** and **chloramphenicol**, drugs like **azithromycin**, **doxycycline**, and **carbapenems** are used for their broad-spectrum effects. **Colistin**, a powerful antibiotic, has recently been in the news due to its use as a last-resort drug against resistant infections.

❖ **Antiseptics and disinfectants**: **Hydrogen peroxide** and **isopropyl alcohol** have become critical, especially in the COVID-19 pandemic for disinfection and hand sanitizers.

Antifertility Drugs

- **Levonorgestrel** and **mifepristone** are commonly used alongside **norethindrone** and **ethynylestradiol** in modern contraceptives.

CHEMICALS IN FOOD

Chemical additives in food include preservatives, sweeteners, and flavoring agents. Recent concerns have arisen around some food additives, sparking discussions on food safety.

Artificial Sweeteners

Apart from **saccharin** and **aspartame**, **sucralose** (Splenda) and **stevia** are now popular as low-calorie sweeteners. Stevia, a plant-based sweetener, is often promoted for its natural origins.

Saccharin is a non-nutritive artificial sweetener that is approximately 300–500 times sweeter than sucrose. **(RAS 2024)**

Food Preservatives

While **sodium benzoate** and **potassium sorbate** are commonly used, concerns about **BHA** (butylated hydroxyanisole) and **BHT** (butylated hydroxytoluene) as potential carcinogens have been raised.

Titanium Oxide and BPA

Titanium dioxide (used in candies and toothpaste) has been controversial due to safety concerns in some studies, leading to a potential ban in several countries. **Bisphenol A (BPA)** in food packaging has also been widely discussed for its possible hormonal effects.

CLEANSING AGENTS

Cleansing agents, both natural and synthetic, play a crucial role in hygiene. However, recent concerns about their environmental impact have drawn attention to safer, biodegradable alternatives. **(RAS 2018)**

Soaps

Traditional soaps like **sodium palmitate** and **sodium stearate** continue to be used, but the environmental impact of soap production, including palm oil related deforestation, has been debated.

Synthetic Detergents

Synthetic detergents, such as **sodium dodecylbenzenesulfonate**, are preferred for their efficiency in hard water. Newer formulations now focus on being biodegradable to prevent pollution.

Environmental Concerns

The use of **phosphates** in detergents has been reduced due to their role in water pollution. **Microplastics** in scrubbing agents, found in cosmetics and cleaning products, have been banned in many countries due to environmental hazards.

IMPORTANT CHEMICALS IN DAILY LIFE AND IN THE NEWS

Certain chemicals, often used in various industries and products, have gained attention recently due to environmental, health, or legal concerns.

PFAS (Per- and Polyfluoroalkyl Substances)

Known as **"forever chemicals,"** PFAS have been in the spotlight for contaminating water supplies. Used in **non-stick cookware, food packaging, and firefighting foam**, they pose significant health risks.

Glyphosate

This widely used herbicide has been the subject of lawsuits due to its potential link to cancer. Countries around the world are reviewing its use in agriculture.

BPA and Phthalates

Both of these chemicals, found in **plastics**, have been under scrutiny for their **hormone-disrupting properties.** BPA-free products are now in high demand as consumers seek safer alternatives.

Aspartame

Aspartame is an artificial sweetener sold in the market. It consists of amino acids and provides calories like other amino acids. Yet, it is used as a low-calorie sweetening agent in food items because aspartame is several times sweeter than table sugar, hence food items made with small quantities of aspartame yield fewer calories on oxidation.

Formaldehyde

Used in household products like glue and furniture, formaldehyde is classified as a carcinogen. Concerns about its presence in air fresheners and cosmetics have led to tighter regulations.

Triclosan

'Triclosan', considered harmful when exposed to high levels for a long time, is most likely present in Toiletries.

Oxybenzone

This chemical, found in **sunscreens**, has been linked to **coral reef damage**. Hawaii and other regions have passed laws banning sunscreens containing oxybenzone to protect marine life.

Plastics

Plastic is widely used for packaging, particularly for bottles and containers. The quality and properties of plastics are classified into various grades depending on their application, molecular weight, and production process.

Code	Plastic Type	Common Uses	Recycling Potential
1	Polyethylene Terephthalate (PET or PETE)	Water bottles, soft drink bottles, food packaging	Easily recycled into fibers, containers
2	High-Density Polyethylene (HDPE)	Milk jugs, detergent bottles, grocery bags	Recycled into pipes, plastic lumber
3	Polyvinyl Chloride (PVC)	Pipes, vinyl flooring, toys, shower curtains	Rarely recycled due to toxic additives
4	Low-Density Polyethylene (LDPE)	Plastic bags, shrink wraps, squeezable bottles	Difficult to recycle, used for liners, tiles
5	Polypropylene (PP)	Yogurt containers, bottle caps, straws, medicine bottles	Recycled into trays, cables, lights
6	Polystyrene (PS)	Disposable cups, plates, food trays, egg cartons	Hard to recycle, used for insulation, packaging

2 Computers, Information and Communication Technology

ELECTROMAGNETIC WAVES

Electromagnetic Waves are a form of energy that travels through space at the speed of light. They are composed of oscillating electric and magnetic fields that are perpendicular to each other and to the direction of propagation.

Characteristics of Electromagnetic Waves

Electromagnetic waves possess several fundamental properties that shape their behaviour and interactions:

- **Transverse Nature:** Oscillations of electric and magnetic fields occur perpendicular to the direction of wave propagation.
- **Wavelength and Frequency:** Each wave is characterised by its wavelength (distance between peaks) and frequency (oscillations per second), which are inversely related.
- **Constant Speed:** In a vacuum, all electromagnetic waves travel at the speed of light.
- **Energy Relationship:** Wave energy is directly proportional to its frequency
- **Medium Independence:** Unlike mechanical waves, electromagnetic waves do not require a medium to propagate.
- **Wave Phenomena:** These waves exhibit reflection, refraction, diffraction, and polarisation, similar to water waves.
- **Matter Interaction:** Electromagnetic waves interact with matter through absorption, transmission, and scattering.
- **Wave-Particle Duality:** Electromagnetic radiation exhibits both wave-like and particle-like properties, behaving as photons in certain contexts.

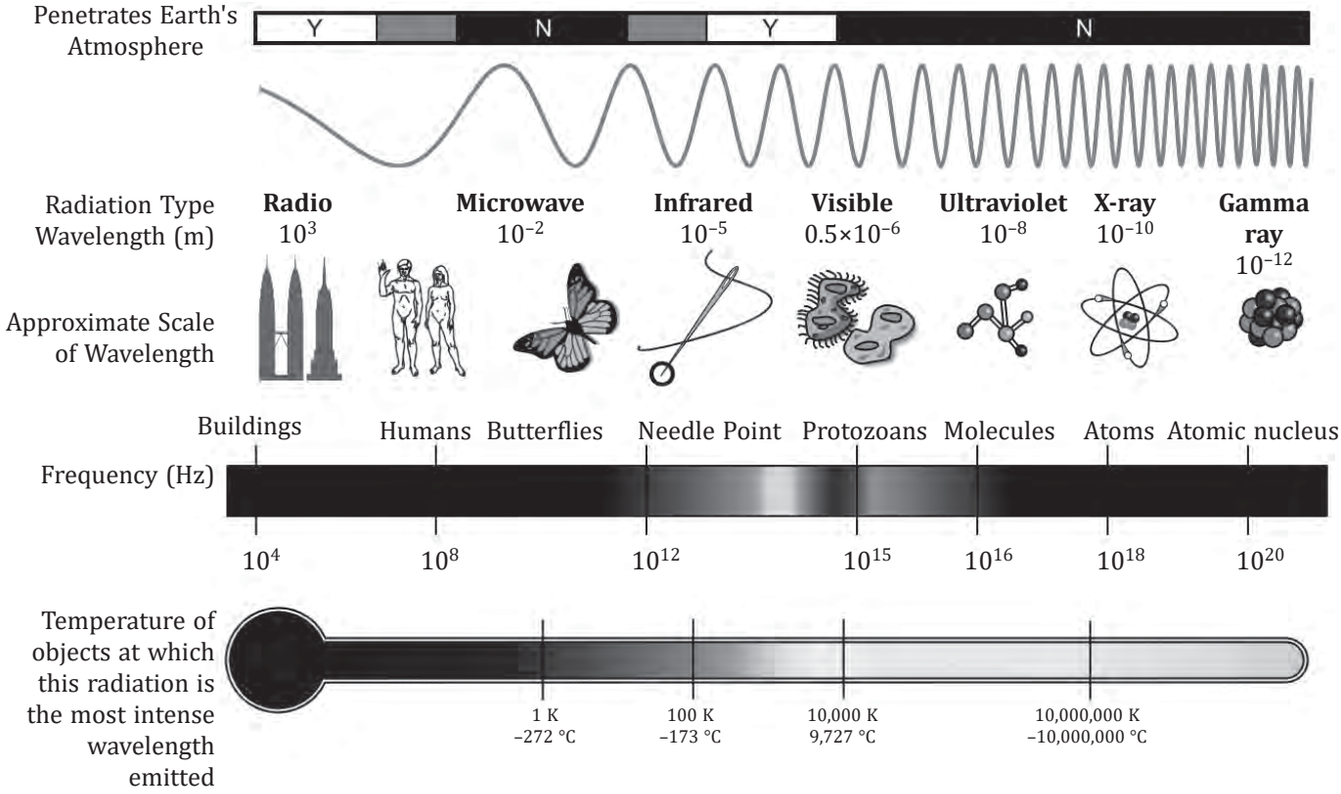


Fig. 2.1: Electromagnetic Spectrum

Electromagnetic Spectrum

The electromagnetic spectrum is a broad range of all types of electromagnetic waves, arranged in order of increasing frequency and decreasing wavelength. It includes:

Type	Penetration in Earth's Atmosphere	Applications
Radio Waves	Penetrate Earth's atmosphere	AM/FM radio, television broadcasts, satellite communication, radar.
Microwaves	Penetrate Earth's atmosphere	Cellular phones, satellite communication, radar, microwave ovens.
Infrared	Partially absorbed by the atmosphere, especially by water vapor and carbon dioxide.	Remote sensing, thermal imaging, night vision, infrared astronomy. and Standard TV remote controls use infrared (IR) rays to transmit signals from the remote to the television. (RAS 2018)
Visible Light	Partially absorbed by Earth's atmosphere	Human vision, photography, optical telescopes.
Ultraviolet	Most of the UV radiation is absorbed by the ozone layer, protecting us from harmful effects.	Medical treatments, sterilization, tanning beds.
X-rays	Absorbed by Earth's atmosphere	Medical imaging (X-rays), industrial applications (radiography).
Gamma Rays	Absorbed by Earth's atmosphere	Medical treatments (radiation therapy), nuclear physics research.

DIFFERENT TYPES OF COMPUTER NETWORKS

Personal Area Network (PAN)

A PAN is the smallest and most personal type of network. Used for communication among devices like smartphones, tablets, laptops etc within a range of about 10 meters.

Local Area Network (LAN) (RAS 2013)

It is a network that is limited to a small geographic area, such as a single building, a campus, or a group of nearby buildings.

E.g., An office network where computers are connected to a shared printer and server.

Metropolitan Area Network (MAN)

It has a larger geographic scope than a LAN but is smaller than a WAN. It typically covers a city or a large campus, connecting multiple buildings within a city or a large campus area.

Wide Area Network (WAN)

It covers a broad area, often spanning across cities, countries, or even continents. It connects multiple LANs and MANs, allowing for the exchange of data over long distances.

Virtual Private Network (VPN)

It is a technology that allows secure and encrypted communication over an untrusted network, such as the internet.

Types of Wave Propagation

- **Ground Wave Propagation**
  - Ground waves travel along the surface of the Earth.
  - Used for low-frequency radio communication (LF and MF bands).
  - Effective for long-distance communication because they follow the Earth's curvature.
- **Sky Wave Propagation**
  - Radio waves are reflected/refracted by the ionosphere and returned to Earth.
  - Mainly used for HF (High Frequency) communication.
  - Enables long-distance radio communication beyond the horizon.
- **Space Wave Propagation (RAS 2018)**
  - Radio waves travel directly from the transmitting antenna to the receiving antenna through the troposphere.
  - Also called Line-of-Sight (LOS) propagation.
  - Used for VHF, UHF, TV broadcasting, mobile communication, radar, and satellite communication.
- **Surface Wave**
  - A mechanical wave that propagates along the interface between two different media.
  - **Example:** Ocean waves moving along the air-water interface.
  - Different from radio-wave propagation.

WIRELESS COMMUNICATION TECHNOLOGIES

- **Bluetooth (RAS 2013):** Short-range wireless technology for connec-ting devices, commonly used for data transfer between devices like smartphones, headphones, and speakers.
  - Can penetrate thin walls and obstacles, but is easily blocked by solid objects like walls or metal.
  - Bluetooth uses 2.4 GHz radio frequency band (RAS 2018)
- **Wi-Fi Direct:** Allows devices to connect to each other directly without the need for a traditional Wi-Fi network.
  - It's useful for peer-to-peer communication between devices.
  - **Penetration:** Similar to standard Wi-Fi, can penetrate thin walls but is blocked by solid objects.
  - Wi-fi can use 2.4 GHz or 5 GHz frequency band **(RAS 2018)**
- **Cordless Phone:** Typically uses Digital Enhanced Cordless Telecommunications (DECT) technology for short-range wireless communication between a phone and its base station.
  - **Penetration:** Can penetrate walls and other obstacles, but signal strength can be affected by distance and interference.
- **Hotspot:** A physical location where people can access the internet, typically using Wi-Fi, through a wireless local area network (WLAN) with a router connected to an internet service provider.
  - **Penetration:** Similar to standard Wi-Fi.
- **Wi-Fi:** Wireless local area networking technology that allows devices to connect to the internet and communicate with each other within a certain range of a Wi-Fi router or access point.
  - Penetration: Similar to Bluetooth, can penetrate thin walls but is blocked by solid objects.
- **WiMAX (Worldwide Interoperability for Microwave Access):** A wireless communication standard that provides high-speed, long-range broadband connections.
  - It's designed for wireless metropolitan area networks (WMANs).
  - **Penetration:** Can penetrate walls and other obstacles, but signal strength can be affected by distance and terrain.
- **Li-Fi:** A wireless communication technology that uses light to transmit data.
  - It is a form of **Visible Light Communication (VLC)** and can provide high-speed, bi-directional communication.
  - It is **more energy efficient than Wifi** and can provide fast communication and connection in spaces such as office, home etc. where light is not intercepted by an obstacle.
  - VLC uses electromagnetic spectrum **wavelengths 375 to 780 nm.** VLC can transmit large amounts of data faster than Bluetooth. VLC has **no electromagnetic interference.**
  - **Penetration:** Limited by the range of visible light, easily blocked by opaque objects.
- **Zigbee:** It is a low-power, low-data-rate wireless communication protocol commonly used for short-range communication between devices in applications like home automation, industrial control, and sensor networks.
- **Infrared (IR):** It involves the use of infrared light for wireless data transfer.
  - It's commonly found in TV remote controls and some short-range communication applications.
- **NFC (Near Field Communication):** It is a short-range wireless communication technology that enables data exchange between devices when they are in close proximity (typically within a few centimetres).
  - It's often used for contactless payments, file sharing, and access control.
  - **Example:** cardless payments through Samsung Pay, Google Pay.
- **RFID (Radio-Frequency Identification):** It uses radio waves to identify and track objects.
  - It is used in logistics, inventory management, and access control systems.
  - An RFID system consists of a tag, which contains a microchip and an antenna, and a reader, which emits radio signals and receives the tag's response.
  - RFID tags can store various kinds of data, such as serial numbers, product information, or personal identification.
  - **Example: FASTag.**

BARCODE & QR CODE

- **Barcode:** A barcode is a method of encoding data in a visual format that can be read by machines. **It stores information in either one-dimensional (1D) or two-dimensional (2D) representations.** Typically composed of a series of bars and spaces, a barcode represents numbers and characters in a way that computers can easily interpret.
- **QR Code:** QR Code stands for Quick Response Code. This technology allows for the storage of information in a **format that can be quickly scanned and understood by devices.** QR codes are especially prevalent in today's fast-moving environment, commonly used for mobile payment systems and other applications requiring swift data retrieval.
- **Barcodes have limited storage capacity** and can typically hold 20-25 characters of numeric data. In contrast, **QR codes have a much larger capacity** and can store up to 7,089 numeric characters or 4,296 alphanumeric characters.

REMOTE SENSING

Remote sensing is the technique of using electromagnetic energy to analyse the physical characteristics of distant objects. It encompasses photography, geophysical surveying, and advanced methods utilising various parts of the electromagnetic spectrum.

Types of Remote Sensors

Remote sensors collect data by detecting reflected energy from the Earth's surface. These sensors can be mounted on satellites or aircraft and are categorised as passive or active:

- **Passive Sensors:** These sensors measure natural energy reflected or emitted from the Earth's surface, primarily sunlight.
- **Active Sensors:** Active sensors emit their own energy, such as a laser beam, and measure the reflected signal to gather information.

Applications of Remote Sensing

- **Agriculture:** Crop identification, forecasting, damage assessment, soil and moisture mapping
- **Oceanography:** Monitoring ocean circulation, currents, temperature, and sea ice
- **Hazard Assessment:** Tracking hurricanes, earthquakes, erosion, and flooding
- **Natural Resource Management:** Land use, wetland mapping, wildlife habitat identification
- **Weather Forecasting:** Analysing weather patterns, precipitation, temperature
- **Environmental Monitoring:** Greenhouse gas sources, canopy chlorophyll, ecosystem health
- **Satellite Remote Sensing:** Land surface temperature, greenhouse gas analysis
- **Aircraft Sensors:** Enhancing satellite data for emission hotspots

LiDAR

LiDAR (Light Detection and Ranging) uses pulsed laser light to measure distances to Earth's surface, providing detailed 3D terrain data.

Key Components & Types: LiDAR includes a scanner, laser, and GPS receiver. Airborne platforms (aeroplanes, helicopters) gather large area data.

Types:

- **Topographic LiDAR:** Maps land with near-infrared lasers.
- **Bathymetric LiDAR:** Uses green light to measure underwater elevations.

How it Works:

LiDAR measures the time for light to reach the ground and return, converting it into elevation data.

Applications:

- Accurate shoreline maps
- Digital elevation models for GIS
- Emergency response assistance

CELLULAR WIRELESS COMMUNICATION TECHNOLOGIES

Mobile phones communicate through ground-based cellular networks. Mobile communication involves transmitting voice or data using wireless radio transmission.

Evolution of Wireless Telecom Technology: From 1G to 6G

Generation	Key Features	Latency	Wave Spectrum
1G	Analog system, poor voice quality, limited roaming	Higher latency	Low frequency (30 MHz - 1 GHz)
2G	Improved voice quality, SMS/MMS, roaming enabled	200 to 400 ms	900 MHz and 1800 MHz
3G	Mobile TV, online radio, video calling	100 to 300 ms	1.8 GHz - 2.5 GHz
4G	LTE system, VoLTE, VoWiFi for better calls	20 to 40 ms	600Mhz - 2.7 GHz
5G	High throughput, ideal for IoT	Low latency (As low as 1 ms)	Uses sub-6 GHz bands (roughly 410 MHz–7.125 GHz) and, in some deployments, mmWave bands above 24 GHz (24–40 GHz).
6G	Data rates over 100 Gbps, AI integration, massive connectivity	Potentially < 1 ms	roughly 100 GHz–1 THz (terahertz bands)

Latency: In mobile networks, **latency** refers to the time delay in data transmission between a device and the network, measured in milliseconds. Lower latency improves user experiences in applications like video calls and online gaming, while 5G aims for latencies as low as 1 ms for enhanced real-time performance.

LTE (Long Term Evolution) and VoLTE

LTE is a wireless broadband standard that enhances mobile network capacity and speed over 3G.

Key Features:

- **High Data Rates**: Download speeds up to 300 Mbps, upload up to 75 Mbps.

- **Reduced Latency**: Ranges from 20 to 40 milliseconds, improving real-time communication.
- **All-IP Architecture**: Integrates voice, video, and data services on an IP network.
- **Applications**: Supports HD video, online gaming, and real-time communications.

VoLTE (Voice over LTE)

VoLTE enabled voice calls over the LTE network, improving voice quality and call setup times.

Key Features:

- **HD Voice Quality**: Offers clearer voice with wideband audio.
- **Simultaneous Data & Voice**: Allows data use during calls without interruptions.
- **Faster Call Setup**: Reduces call setup to about 2 seconds.
- **Applications**: Ideal for video conferencing and emergency services.

Standalone and Non-Standalone 5G Networks

5G networks can be deployed in two primary modes: standalone and non-standalone.

- **Standalone (SA) 5G:**
  - Operates with dedicated equipment, independent of the existing 4G network.
  - Offers the full range of 5G capabilities, including network slicing for enhanced flexibility and efficient spectrum utilization.
- **Non-Standalone (NSA) 5G:**
  - Relies on the 4G core network for support.
  - Provides a faster and more cost-effective rollout compared to SA 5G, as it leverages existing infrastructure.
  - Allows operators to maximize the utilization of their existing network investments.

Voice over Internet Protocol (VoIP)

It utilizes IP-enabled devices and broadband connectivity to **convert voice into digital packets,** which are then transmitted over a packet-switched network.

Advantages of VoIP: Cost-effective, Integrate with other communication tools like video conferencing and email, Call forwarding, voicemail, call recording, call waiting.

VoWiFi: Voice Calls over Wi-Fi

- Wi-Fi Calling makes use of high speed Internet connection, available via broadband, to make and receive high definition (HD) voice calls. Users don't have to pay extra for these calls as it is using a Wi-Fi network.
- Wi-Fi Calling is aimed especially for areas where cellular networks are not strong.
- This is **not much different from a voice call using WhatsApp or any other over-the-top messaging platform,** but here the call is from one number to another, and not using an app.

Benefits: seamless switching between LTE and Wi-Fi networks, ensuring uninterrupted calls, extending voice coverage to areas with poor cellular reception; improved call quality; reduced cellular data usage, potentially leading to cost savings.

Internet of Things (IoT)

IoT is a network of interconnected devices with unique identifiers, enabling **machine-to-machine (M2M) communication without human intervention.**

- These devices, equipped with sensors, software, and communication technologies, collect, transmit, and act upon data from their environments.

Applications of IoT: Smart Infrastructure like Power grids, transportation, safety and surveillance systems; Remote Management of Healthcare and agriculture; Smart Homes and cities.

Role of 5G and Edge Computing in IoT

- **Enhanced Connectivity:** 5G provides the high-speed, low-latency connectivity required for IoT devices to transmit and receive data efficiently.
- **Reduced Latency:** Edge computing enables real-time data processing and analysis, reducing latency and improving response times for IoT applications.
- **Increased Capacity:** 5G and edge computing together can handle the massive amount of data generated by IoT devices, ensuring seamless operation.
- **Improved Reliability:** Edge computing can provide redundancy and fault tolerance, ensuring that IoT applications continue to function even in the event of network disruptions.
- **Enhanced Security:** Edge computing can help improve data security by processing sensitive data closer to the source, reducing the risk of data breaches.
- **New Applications:** 5G and edge computing enable new IoT applications, such as autonomous vehicles, smart cities, and industrial automation.
- **The Network Layer:** The Network Layer in IoT enables communication between devices through wireless technologies such as Wi-Fi, Bluetooth, ZigBee, and cellular networks. (RAS 2024)

Platform Sharing in Cellular Communication

Platform sharing in cellular communication refers to the collaborative arrangement where multiple Mobile Network Operators (MNOs) share infrastructure components, such

as base stations, towers, and backhaul networks.

- This practice offers several benefits, including cost reduction, improved network efficiency, and accelerated deployment of new technologies.

Key Aspects of Platform Sharing:

- **Infrastructure Sharing:** MNOs can share various infrastructure components, including:
  - **Base stations:** The physical structures that transmit and receive radio signals.
  - **Towers:** The structures that support base stations.
  - **Backhaul networks:** The high-speed networks that connect base stations to the core network.
- **Sharing Models:** Different sharing models can be adopted, such as:
  - **Active Sharing:** MNOs jointly operate and manage shared infrastructure.
  - **Passive Sharing:** One MNO owns and manages the infrastructure, while others lease access.
  - **Hybrid Sharing:** A combination of active and passive sharing.
- **Benefits of Platform Sharing:**
  - **Cost Reduction:** Sharing infrastructure can significantly reduce capital and operational expenses for MNOs.
  - **Improved Network Efficiency:** By optimising resource utilisation, platform sharing can enhance network performance and coverage.
  - **Accelerated Deployment:** Sharing infrastructure can expedite the rollout of new technologies, such as 5G, by leveraging existing infrastructure.
  - **Reduced Environmental Impact:** Sharing infrastructure can help reduce the environmental footprint of cellular networks by minimizing the number of towers and base stations.

Key Technologies for Platform Sharing

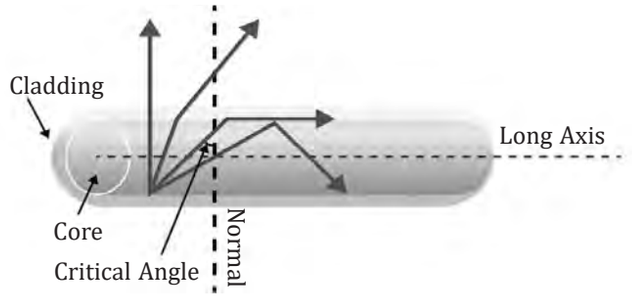
- **Network Slicing:** This technology allows MNOs to create virtual networks within a shared physical infrastructure, providing tailored services to different customer segments.
- **Shared Spectrum:** By sharing spectrum resources, MNOs can optimize their network capacity and reduce costs.
- **O-RAN (Open Radio Access Network):** O-RAN is an open, modular architecture that enables interoperability and flexibility in network deployment. It can facilitate platform sharing by decoupling hardware and software components.

FIBER OPTICS AND INTERNET

Fiber Optics

Optical fiber is a technology that uses light pulses to transmit data through long, thin strands of glass or plastic. Unlike traditional metal wires, optical fibers offer superior signal transmission with minimal attenuation.

Fiber Optic Internal Reflection



The Principle of Total Internal Reflection (TIR)

- Optical fibers operate based on the principle of total internal reflection.
- In TIR, light gets reflected on moving from denser to rarer medium if angle of incidence is greater than critical angle.
- This phenomenon occurs when light rays traveling within a medium (like glass) strike the boundary with another medium (like air) at an angle greater than the critical angle.
- The light rays are then reflected back into the original medium, allowing them to travel along the fiber without significant loss.

SURFACE WEB, DEEP WEB, AND DARK WEB

The internet can be broadly divided into three layers: the Surface Web, Deep Web, and Dark Web.

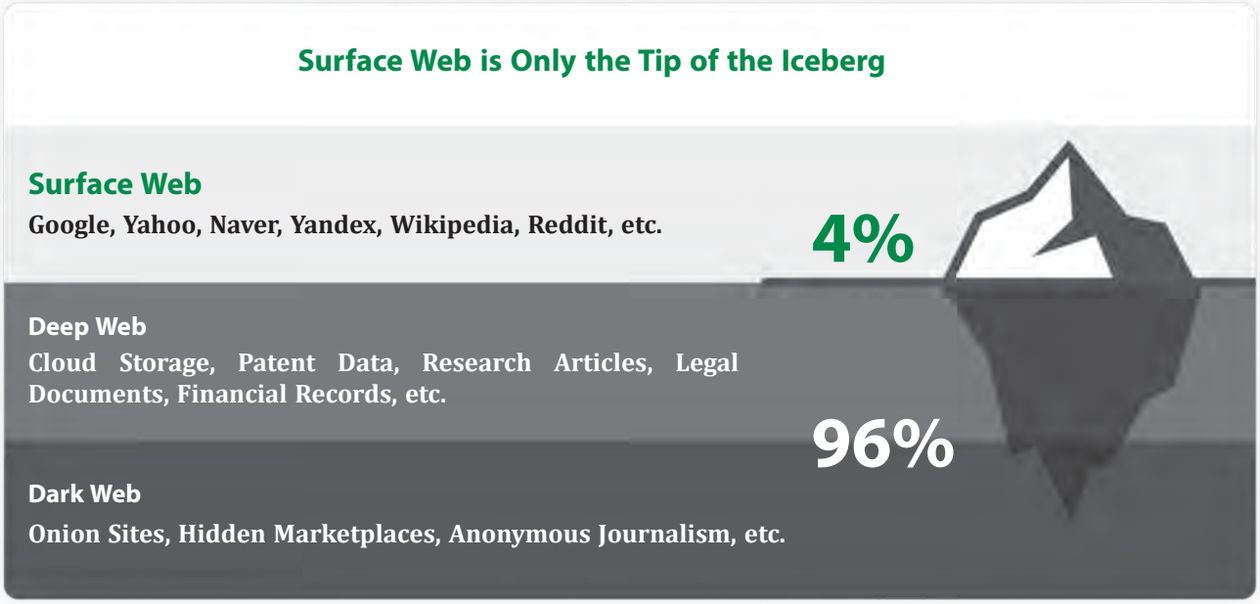
Surface Web

The surface web is the portion of the internet that is readily accessible to users using standard search engines like Google and Yahoo. However, it only represents a small fraction of the total internet content, **estimated to be around 4%.**

Deep Web

The deep web encompasses a vast portion of the internet, comprising **approximately 96%** of websites that are not publicly accessible. These websites are typically protected by passwords or paywalls, restricting access to authorized individuals.

- Examples include online banking portals, personal databases, social media accounts, scientific and academic databases, and legal documents.
- This hidden realm of the internet contains a wealth of information that is not readily available to the general public.


Surface Web is Only the Tip of the Iceberg
Surface Web
Google, Yahoo, Naver, Yandex, Wikipedia, Reddit, etc.
4%
Deep Web
Cloud Storage, Patent Data, Research Articles, Legal Documents, Financial Records, etc.
96%
Dark Web
Onion Sites, Hidden Marketplaces, Anonymous Journalism, etc.

Dark Web

The **darknet is a subset of the deep web,** characterized by its deliberate anonymity and inaccessibility through standard search engines. Unlike the deep web, which can be accessed with specialized tools, the darknet requires specific browsers and networks to access its content.

Key Features of the Darknet

- **Anonymity:** The darknet prioritizes anonymity, using encryption and routing techniques to hide user identities and protect their online activities.
- **Accessibility:** Requires specialized browsers like Tor, Freenet, I2P, and Tails to access.
- **Content:** Hosts a wide range of content, including legal and illegal activities, such as marketplaces, forums, and whistleblowing platforms.

The Tor Network

Developed by the U.S. Naval Research Laboratory, Tor (The Onion Router) is the most widely used browser for accessing the darknet. It employs a layered routing system to obscure user identities and traffic patterns, making it difficult to track online activities.

White Space Internet

White Space Internet is a type of wireless broadband technology that **utilizes the unused frequency bands between television channels.** These "white spaces" are available for radio communication applications in certain geographical areas and times.

Features of White Space Internet: utilizes the unused frequency bands between television channels; Long-Range Coverage; can penetrate obstacles like buildings, foliage, and hills; Cost-Effective; easily deployed and reconfigured.

BLOCKCHAIN TECHNOLOGY

Blockchain, a type of **Distributed Ledger Technology (DLT),** is a decentralised digital infrastructure that enables secure and transparent storage and transfer of information. Originally developed for Bitcoin, it has found applications in various sectors, including finance, supply chains, and voting.

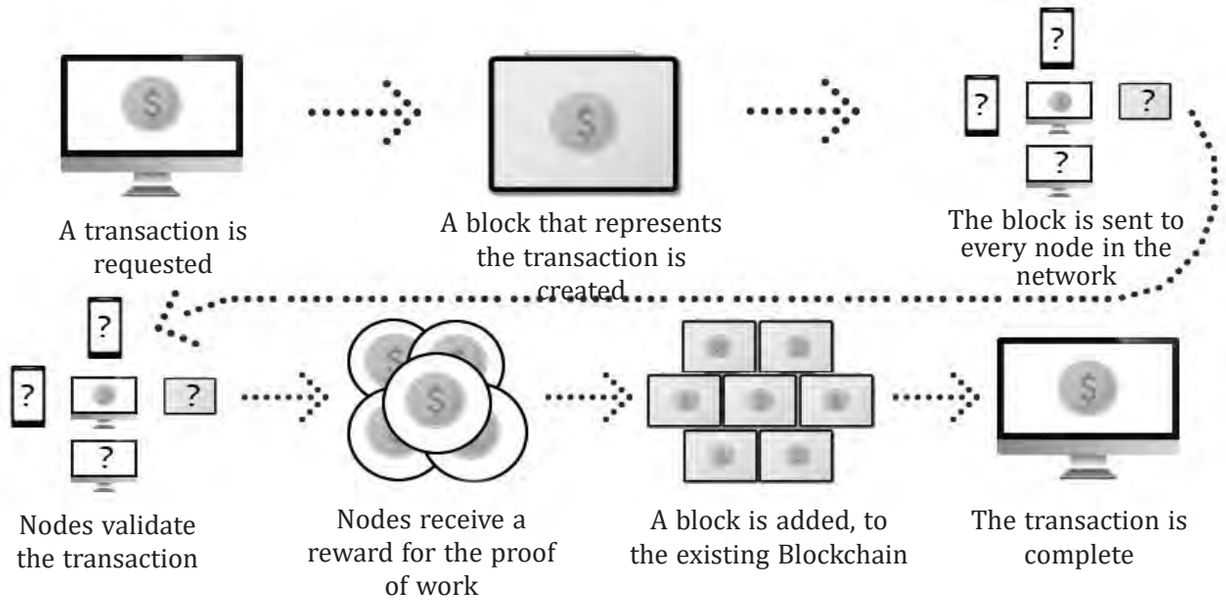
Key Features of Blockchain:

- **Decentralization:** No central authority controls the network, making it resistant to censorship and manipulation.
- **Immutability:** Transactions are recorded as blocks and added to a chain, making them irreversible.
- **Transparency:** All transactions are visible to the public, ensuring transparency and accountability.
- **Security:** Blockchain uses cryptographic techniques to secure data and prevent tampering.
- **Energy Intensive:** Each block in the blockchain is added by solving complex calculations by the peers which needs high computational capacities and thus high energy consumption.

Evolution of Blockchain:

- **Origin:** Inspired by Ralph Merkle's hash tree data structures, **Satoshi Nakamoto** introduced blockchain for Bitcoin in 2008.
- **Ethereum:** Ethereum expanded blockchain capabilities with smart contracts, enabling more complex applications.

How Blockchain Works?


A transaction is requested
A block that represents the transaction is created
The block is sent to every node in the network
Nodes validate the transaction
Nodes receive a reward for the proof of work
A block is added, to the existing Blockchain
The transaction is complete

- **Growth:** Blockchain is now rapidly evolving and finding new applications across various industries.

Applications:

- **Financial Services:** Cryptocurrencies **(**Bitcoin and Ethereum), Payments and Trading (Singapore Exchange Limited), **Central Bank Digital Currency (CBDC)-** also known **e-Rupee** is based on blockchain technology.
- **Healthcare:** Medical Records, Drug Supply Chain
- **Copyright Management:** Protecting and managing copyright data, as demonstrated by Sony Music Entertainment.
- **Blockchain-as-a-Service (BaaS) - Cloud-Based Block-chain Solutions:** Third-party providers offer BaaS to simplify blockchain application development.

Non-Fungible Tokens (NFTs)

Fungible refers to something that is interchangeable with another item of the same kind. For example, in the case of money or cryptocurrency, one unit is identical to another unit of the same value and can be exchanged without any difference. In contrast, non-fungible items, like NFTs, are unique and cannot be exchanged on a one-to-one basis with something else, as each has its own individual value.

NFTs are unique digital assets that represent ownership of real or virtual items. They are created on blockchains, such as **Ethereum,** and are assigned unique identification codes and metadata. **Unlike fungible tokens like money, each NFT is distinct and cannot be exchanged for another.**

NFTs can represent a wide range of items, including:

- **Digital art:** Paintings, photographs, music, videos
- **Real-world items:** Real estate, collectibles, physical goods
- **Intellectual property:** Patents, copyrights, trademarks
- **Identities:** Personal or corporate identities

NFTs **can be traded and exchanged for other NFTs, cryptocurrencies, or fiat currency, depending on their perceived value.** Transactions are recorded on blockchains, providing a transparent and secure record of ownership.

NFTs gained significant popularity in 2021 as artists recognized their potential for monetizing their work.

Evolution of Web (Web 1.0, 2.0, 3.0, and 5.0)

- **Web 1.0**: Often referred to as the "read-only web," was the first stage of the World Wide Web. It existed roughly from the mid-1990s to the early 2000s.
- **Web 2.0**: Refers to the second generation of the World Wide Web, characterized by a shift from static web pages to dynamic and interactive content. The term was popularized around the early 2000s.
- **Web 3.0**: It is the idea of a new internet that gives **users more control over their data** and privacy, using decentralization, blockchain, and tokenomics. It aims to offer a personalized and interactive experience but is still in development and not fully implemented. **Examples:** Siri, Alexa, Google Assistant, and Ethereum.
- **Web 4.0**: Web 4.0 is an emerging concept that builds upon Web 3.0 by integrating artificial intelligence, autonomous systems, and seamless human–machine interaction. It is still in the early stages of development, with broader adoption expected during the late 2020s and beyond.
- **Web 5.0**: This is the ultimate stage of the web, expected to emerge by 2030. It is also called the **emotional web,** as it anticipates a web that can understand and respond to the emotions, values, and preferences of the users.

Cryptocurrency

Cryptocurrency is a digital or virtual currency that utilizes cryptography for security. Unlike traditional currencies, cryptocurrencies are decentralized, meaning they are not controlled by a central authority like a government or bank.

- Popular examples of cryptocurrencies include Bitcoin, Ethereum, and Litecoin.
- These digital assets are often traded on decentralised exchanges and can be used for various purposes, such as purchasing goods and services, investing, or sending and receiving money.

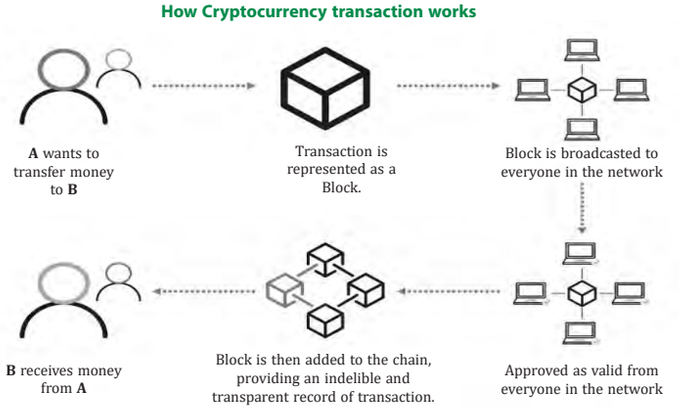
Legal Status of Cryptocurrency

The legal status of cryptocurrency varies significantly across countries. While some have embraced it, others have adopted a more cautious approach.

Cryptocurrency in India

- **RBI Warnings:** The Reserve Bank of India (RBI) has issued warnings against the use of cryptocurrencies, citing potential risks to investors.
  - RBI has introduced **Central Bank Digital Currency (CBDC) which is not a Cryptocurrency** as it's value is fixed by Central bank unlike cryptocurrencies which have different mechanism of value setting. CBDC however is also based on blockchain technology like cryptocurrency.
- **Supreme Court Ruling:** In 2018, the Supreme Court overturned an RBI ban on financial institutions dealing with cryptocurrencies.
- **Taxation and Regulation:** The government has introduced a **30% tax on cryptocurrency transactions** and established a panel to explore blockchain technology and a potential Central Bank Digital Currency (CBDC).

How Cryptocurrency transaction works


A wants to transfer money to B
Transaction is represented as a Block.
Block is broadcasted to everyone in the network
B receives money from A
Block is then added to the chain, providing an indelible and transparent record of transaction.
Approved as valid from everyone in the network

Global Landscape

- **Legal Tender:** El Salvador and the Central African Republic are the only countries where Bitcoin is legal tender.
- **Recognition and Regulation:** Many countries have taken steps to recognize and regulate certain cryptocurrencies.
- **Restrictions:** Some countries, like China and Russia, have imposed restrictions on cryptocurrency use.

Cryptocurrency vs NFT: Cryptocurrencies are fungible, meaning they are interchangeable and primarily used as a medium of exchange and a store of value. Their value is derived from market demand and supply, and they are traded on cryptocurrency exchanges (e.g., Bitcoin, Ethereum).

In contrast, NFTs (Non-Fungible Tokens) are unique and represent ownership of digital assets. Their value is subjective, based on the asset and market sentiment, and they are traded on NFT marketplaces (e.g., CryptoPunks, Bored Ape Yacht Club).

Consensus Mechanism in Cryptocurrency

Proof of Work (PoW) and **Proof of Stake (PoS)** are two primary consensus mechanisms used in blockchain technology to validate transactions and secure the network. They differ significantly in their approaches and implications.

Proof of Work (PoW)

- **Consensus Mechanism:** Miners compete to solve complex cryptographic puzzles. The first miner to solve the puzzle adds the next block to the blockchain.

- **Reward:** Miners receive newly minted cryptocurrency as a reward for their computational effort.
- **Security:** The computational power required to attack the network makes it highly secure.
- **Energy Consumption:** PoW is energy-intensive due to the computational resources needed for mining.
- **Examples:** Bitcoin, Ethereum (before the Merge)

Proof of Stake (PoS)

- **Consensus Mechanism:** Validators are selected based on the amount of cryptocurrency they stake in the network. The selected validator adds the next block to the blockchain.
- **Reward:** Validators earn transaction fees or newly minted cryptocurrency as a reward.
- **Security:** The economic incentive to act honestly prevents malicious behavior, as validators risk losing their stake if they misbehave.
- **Energy Efficiency:** PoS is significantly more energy-efficient than PoW.
- **Examples:** Ethereum (after the Merge), Cardano, Solana

Other Consensus Mechanisms

Delegated Proof of Stake (DPoS): In this system (used by networks like EOS and Tron), participants delegate their tokens to trusted validators who are then responsible for validating blocks. Those validators earn the minted cryptocurrency, which is often shared with delegators.

Minting Through Smart Contracts: Certain decentralized applications (DeFi(Decentralise Finance) projects for instance) mint new tokens based on rules encoded in smart contracts. These can be rewards for staking tokens or participating in specific network activities.

CBDC vs. e-RUPI

Central Bank Digital Currency (CBDC) and **e-RUPI** are both digital payment solutions, but they serve different purposes and operate under distinct mechanisms.

CBDC

- **Issuer:** Issued and regulated by a central bank, such as the Reserve Bank of India (RBI).
- **Purpose:** Intended to replace physical currency and provide a digital alternative for transactions.
- **Scope:** Covers a wide range of transactions, from daily purchases to large-scale payments.
- **Technology:** Can be based on various technologies, including blockchain.
- **Accessibility:** Accessible to the general public through banks and other financial institutions.

e-RUPI

- **Issuer:** Issued by the National Payments Corporation of India **(NPCI**) in collaboration with government departments.
- **Purpose:** Designed as a pre-paid, one-time payment instrument for specific goods or services.
- **Scope:** Primarily used for government welfare schemes and employee benefits.
- **Technology:** Based on **QR codes and UPI** (Unified Payments Interface).
- **Accessibility:** Available only to specific beneficiaries as designated by the issuing authority.

Blockchain Technology in India: Government Initiatives

- **Regulatory Sandbox:** The Reserve Bank of India (RBI) has established a regulatory sandbox to facilitate innovation in blockchain-based cryptocurrency and exchange solutions.
- NBFLite, a Blockchain sandbox platform, is developed by Ministry of Electronics & IT for startups/academia capacity building.
- **National Blockchain Strategy (2021):** The government has proposed a national strategy to promote blockchain adoption, including the development of state-specific applications and a reliable digital platform for e-governance services.
- **State-Level Initiatives:** States like Telangana, Tamil Nadu, and Maharashtra have invested in blockchain centres of excellence and startup incubators to foster blockchain innovation.
- **Digital India:** The Union Government has recognized blockchain as a key emerging technology under the Digital India initiative.
- **Centre of Excellence:** The **National Informatics Centre** has established a Centre of Excellence for Blockchain Technology to promote a unified, interoperable blockchain ecosystem across the country.

ENCRYPTION

Encryption is the process of scrambling data to make it unreadable to unauthorized parties. It involves using a cryptographic key, a set of mathematical values shared by the sender and recipient.

Types of Encryption

- **Symmetric Encryption:** Uses a single, shared key for both encryption and decryption.
- **Asymmetric Encryption (Public Key Encryption):** Uses two separate keys: a public key for encryption and a private key for decryption.

End-to-End Encryption

End-to-end encryption is a security measure that ensures data shared between two devices remains confidential.

- It prevents third parties, such as cloud service providers, internet service providers, and cybercriminals, from accessing or intercepting the data during transmission.
- **Examples:** Messaging apps like WhatsApp, Signal, and Telegram; Email services that support end-to-end encryption; Virtual private networks (VPNs) that use end-to-end encryption to secure internet traffic

How it Works:

- **Cryptographic Keys:** Unique cryptographic keys are generated and stored on the sender's and recipient's devices.
- **Encryption:** The data is encrypted using a complex algorithm, transforming it into an unreadable format.
- **Decryption:** Only the devices with the corresponding decryption keys can decode the encrypted data.

Quantum Key Distribution (QKD)

QKD, a type of quantum cryptography, provides a highly secure method for distributing and sharing secret keys used in cryptographic protocols.

- Unlike traditional cryptosystems that rely on complex mathematical algorithms, QKD leverages the laws of physics for security.
- **Benefits of QKD:** Unconditional Security, Long-Distance Transmission, Enhanced Privacy.
- **Applications:** Government and Military, Financial Institutions, Research and Development.

How QKD Works:

- **Quantum Bits (Qubits):** Encryption keys are transmitted as qubits through optical fibers.
- **Total Internal Reflection:** Optical fibers enable efficient and long-distance data transmission.
- **Authentication:** Legitimate users must authenticate their interactions to ensure secure key distribution.
- **Secure Key Generation:** QKD allows two parties to generate a shared, random secret key.
- **Detection of Eavesdropping:** Any attempt to intercept the transmission will disturb the qubits, alerting the legitimate users.

BIG DATA AND COMPUTING

Big Data

Big data refers to a vast amount of structured, semi-structured, or unstructured data that is so voluminous that traditional data processing methods become inadequate.

- It encompasses not only the sheer quantity of data but also the challenges of collecting, storing, and analyzing it effectively.

Data Engineering and Data Science

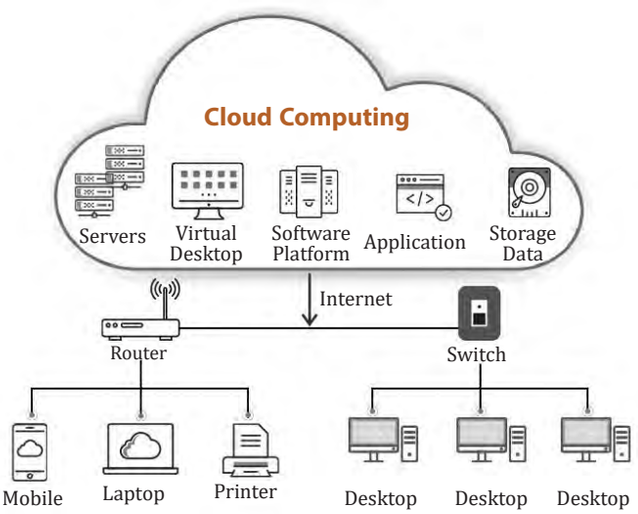
Data Engineering

- Data engineering involves designing, building, and maintaining data infrastructure to support data science and analytics initiatives.
- Data engineers extract, transform, and load (ETL) data from various sources, ensuring data quality and consistency.
- They work closely with data scientists to understand data requirements and build efficient data pipelines.

Data Science

- Data science is the interdisciplinary field of extracting insights and knowledge from data using statistical and machine learning techniques. Data scientists collect, clean, analyze, and interpret data to solve problems and make informed decisions.
- Deep learning is a specialized branch of machine learning, which itself falls under artificial intelligence (AI). It uses multi-layered artificial neural networks such as convolutional neural networks (CNNs) and recurrent neural networks (RNNs) to learn complex patterns from large datasets, excelling in image recognition, speech, and language tasks, while traditional machine learning includes broader algorithms like decision trees and SVMs.
- The Majorana 1 chip, developed by Microsoft and announced on February 19, 2025, is the world's first Quantum Processing Unit (QPU) using a Topological Core architecture based on topoconductors (indium arsenide and aluminum). Microsoft claims the chip can scale up to 1 million qubits and enable fault-tolerant quantum computing for fields like drug discovery, cryptography, and materials science.

Cloud Computing



Cloud computing is a technology model that enables access to computing resources, such as storage and

processing power, over the internet. Instead of relying on a local server, users can access these resources through web-based tools and applications. This on-demand access offers flexibility, scalability, and cost-effectiveness.

How it Works:

Cloud computing involves storing and managing data on remote servers accessible via the internet. This centralised approach offers several key benefits:

- **Resource Pooling:** Dynamically allocates physical and virtual resources based on user demand.
- **On-Demand Access:** Provides scalable services that are available as needed, often with a pay-as-you-go pricing model.
- **Data Management:** Users can easily retrieve, manage, and interact with their data and applications hosted on the cloud.
- **Virtualization:** Creates and manages scalable virtual machines and environments using virtualization technology.
- **Automated Management:** Automates system maintenance tasks, including backup, updates, and security.
- **Accessibility:** Enables access from any device with internet connectivity, facilitating remote work and data sharing.

Cloud-Based Services

Cloud-based services offer flexible, scalable solutions through different service models, primarily structured around a subscription model. The three main service models are:

1. **Infrastructure as a Service (IaaS)**
   - **Definition:** Provides virtualized computing resources (servers, networks, storage).
   - **Applications:** Web hosting, big data analysis, e-commerce platforms.
   - **Examples:** Amazon EC2, MeghRaj Initiative.
   - **Access:** Clients provision resources via a web interface; service providers manage the hardware.
2. **Platform as a Service (PaaS)**
   - **Definition:** Manages application deployment without the need for hardware or OS management.
   - **Applications:** Application development, business analytics, disaster recovery.
   - **Examples:** Microsoft Azure App Service, AWS Elastic Beanstalk.
   - **Access:** Clients deploy apps through a dashboard; providers handle platform infrastructure.
3. **Software as a Service (SaaS)**
   - **Definition:** Offers complete software solutions with no maintenance required.
   - **Applications:** CRM, email, content management systems.
   - **Examples:** Microsoft Office 365, Google Workspace, DigiLocker.
   - **Access:** Clients use a web browser/app for access; providers maintain the software.

Subscription Model

- **Structure:** Clients pay recurring fees for access to services, with various tiers available (e.g., personal, business, enterprise).
- **Example:** Microsoft Office 365, where clients choose subscription levels based on their needs.

Dashboards and Access

- **Client Dashboards:** Clients can customize their dashboards to monitor usage and performance metrics.
- **Service Provider Dashboards:** Providers use dashboards to manage resources and service performance.
- **Editing Permissions:** Clients can edit their dashboards but cannot change underlying systems. Service providers can modify overall service settings.

Login IDs

- **Client Login IDs:** Unique IDs for secure access, allowing management of user roles.
- **Service Provider Login IDs:** Higher-level access for managing the service and providing support.

MeghRaj

It is a cloud computing initiative of the Government of India. It is a set of discrete cloud computing environments spread across multiple locations, built on existing or new (augmented) infrastructure, following a set of common protocols, guidelines and standards issued by the Government of India.

Edge Computing

Edge computing refers to the practice of processing data closer to its source, rather than relying on centralized cloud servers. This reduces latency and improves response times by eliminating the need to transmit data over long distances.

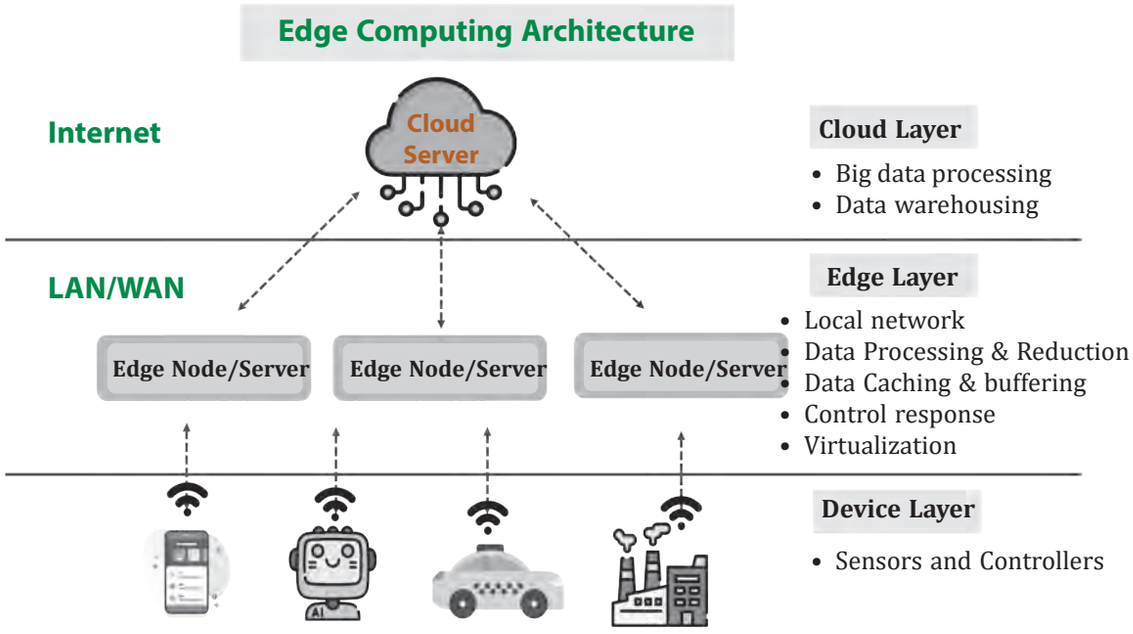


Fig. 2.2: Edge computing architecture overview

Key Features of Edge Computing

- **Decentralized Processing:** Data is processed at the edge of the network, near the source of data generation (e.g., IoT devices, smartphones).
- **Reduced Latency:** By processing data locally, edge computing minimizes delays and ensures faster responses.
- **Real-Time Analysis:** Data can be analyzed in real-time, enabling timely decision-making and actions.

Applications of Edge Computing

- **Internet of Things (IoT):** Processing data from IoT devices for real-time applications.
- **Autonomous Vehicles:** Processing sensor data for self-driving capabilities.
- **Virtual Reality:** Rendering graphics and processing data locally for immersive experiences.
- **Augmented Reality:** Processing data from cameras and sensors for real-time overlays.

Cloud Vs. Edge Computing

Feature	Cloud Computing	Edge Computing
Data Processing	Non-time-sensitive	Real-time, high-speed
Internet Connectivity	Requires reliable internet	Limited or no internet needed
Use Cases	Dynamic workloads, large datasets	Highly sensitive data, real-time analysis
Cost	Costly for large datasets	Cost-effective for large datasets
Data Storage	Places data in cloud storage	Processes data locally

Supercomputers

Supercomputers are high-performance computing systems designed to handle complex computational tasks. They utilize multiple processors to divide and conquer problems, accelerating processing speeds. The performance of supercomputers is measured in **Floating-point Operations Per Second (FLOPS).**

Leading Supercomputers of World

The landscape of supercomputing is constantly evolving, with new and powerful machines emerging regularly. As of now, the following supercomputers occupy the top positions:

- **EI Capitan:** Became the world's fastest supercomputer in Nov 2024 attaining speed of 1.742 exaFLOPS, beating the Frontier.
- **Frontier** is now the second fastest supercomputer in the world reaching maximum speed of 1.1 **exaFLOPS.**
- **Sunway TaihuLight (China), Tianhe-2 (China), Dell Frontera (USA), Piz Daint (Switzerland), and AI Bridging Cloud Infrastructure (ABCI) (Japan).** These are other notable supercomputers on the list.

The United States currently leads in terms of the number of supercomputers in the top 10, followed by China.

Supercomputers in India

India's supercomputing journey was spurred by the U.S. **denial of a Cray X-MP supercomputer in 1987.** This led to the establishment of domestic capabilities in supercomputer development.

- **C-DAC:** The Centre for Development of Advanced Computing has been a pioneer in supercomputing, developing the PARAM series.
- **BARC and ANURAG:** These organizations have also contributed to supercomputing development in India, creating the Anupam and PACE series, respectively.
- **PARAM Series:** C-DAC's PARAM series has been a cornerstone of Indian supercomputing, with notable achievements like the PARAM 8000 and PARAM 10000.
- **AIRAWAT:** India's fastest supercomputer as of June 2023, ranked around 75th globally.
- **PARAM Siddhi – AI:** Another high-performance supercomputer focused on AI applications.
- **Mihir (NCMRWF, Noida):** Supports medium-range weather forecasting and scientific simulations.

Quantum Computing

Quantum computing is a revolutionary field that harnesses the principles of quantum mechanics to perform calculations far beyond the capabilities of classical computers. Unlike classical computers, which use bits (0s or 1s), quantum computers utilize qubits.

Qubits

A qubit, the fundamental unit of quantum information, is a quantum-mechanical system capable of existing in multiple states simultaneously.

Quantum Principles

Quantum computing relies on several fundamental principles that differentiate it from classical computing.

- **Superposition:** Unlike classical bits, quantum bits (qubits) can exist in multiple states simultaneously, a concept known as superposition. This enables quantum computers to process information in parallel, potentially solving complex problems much faster than classical computers.
- **Entanglement:** Quantum particles can become entangled, meaning their states are interconnected regardless of distance. This phenomenon allows for unique correlations and is essential for certain quantum algorithms.
- **Interference:** Quantum particles exhibit wave-like behavior, leading to interference effects that can be harnessed for computational tasks.
- **Tunneling:** Quantum particles can pass through barriers that would be impenetrable according to classical physics, a phenomenon known as tunneling. This principle is crucial for the operation of quantum computer hardware like **quantum dots.**

Qubit

A qubit, the fundamental unit of quantum information, is a quantum-mechanical system capable of existing in multiple states simultaneously.

- This phenomenon, known as superposition, distinguishes qubits from the bits used in traditional computers.
- Unlike bits, which can only represent 0 or 1, qubits can represent both 0 and 1 or any combination of the two states.
- This unique property enables quantum computers to perform complex calculations and solve problems that are intractable for classical computers.

Quantum Supremacy

Quantum supremacy refers to the ability of a quantum computer to perform certain calculations significantly faster than a classical computer.

- The term "Quantum Supremacy" was coined by John Preskill in 2011. In 2019, Google made headlines by achieving quantum supremacy with its 53-qubit quantum processor, **Sycamore.**
- The Sycamore successfully solved a sampling **problem in approximately 200 seconds,** a task that would have taken the **world's fastest classical supercomputer over 10,000 years** to complete.

Difference between Classical and Quantum Computing

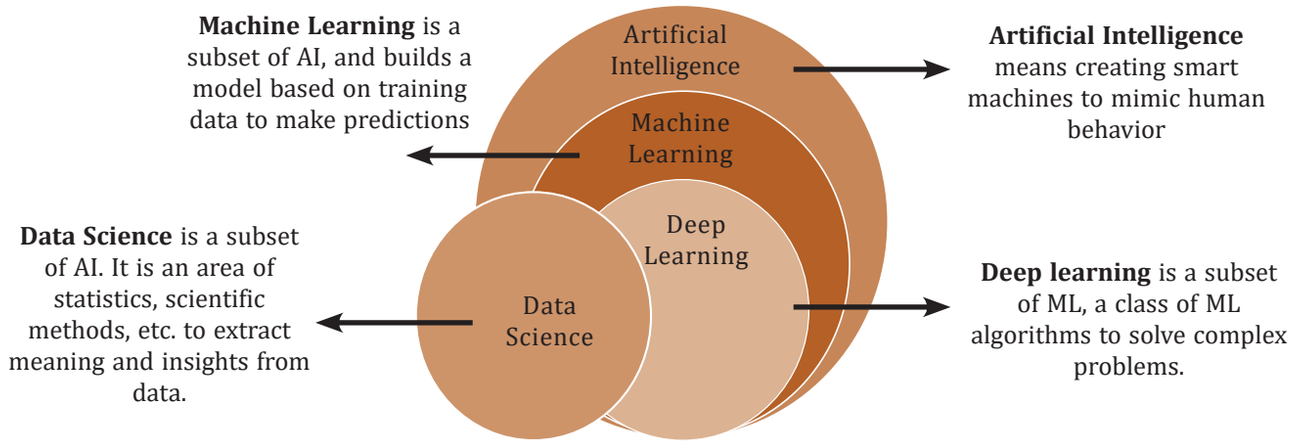
Parameter	Classical Computing	Quantum Computing
Basic Unit	Uses bits that are either 0 or 1.	Uses qubits that can be 0, 1, or both at the same time (superposition).
Parallelism	Works on tasks one after the other (sequentially).	Can work on many tasks at once because of superposition.

Hardware	Built with regular silicon chips that work at normal temperatures.	Uses special quantum processors that need to be kept very cold (cryogenic).
Programming	Follows a clear, step-by-step set of instructions.	Sets up conditions to find solutions using probabilities, not just direct steps.
Speed	Speed is limited by the number of transistors in the chip.	Can potentially solve certain problems much faster than classical computers.
Accuracy	Gives precise, reliable results.	Results can be uncertain and may require corrections (quantum error correction).

Artificial Intelligence and Machine Learning (RAS 2024)

AI is the ability of a computer, or a robot **controlled by a computer to do tasks that are usually done by humans** because they require human intelligence and discernment.

- Alan Turing proposed "**Turing Test**" to evaluate machine intelligence.
- John McCarthy coined the term "Artificial Intelligence".


Machine Learning is a subset of AI, and builds a model based on training data to make predictions
Artificial Intelligence
Machine Learning
Deep Learning
Data Science
Artificial Intelligence means creating smart machines to mimic human behavior
Data Science is a subset of AI. It is an area of statistics, scientific methods, etc. to extract meaning and insights from data.
Deep learning is a subset of ML, a class of ML algorithms to solve complex problems.

Components of Artificial Intelligence: Artificial Intelligence (AI) encompasses several core technologies that enable intelligent systems. These include:

- **Machine Learning:** Algorithms that allow systems to learn from data and improve their performance over time without explicit programming. **Example:** Spam filtering in email clients.
- **Deep Learning:** A subset of machine learning that utilizes artificial neural networks with multiple layers for complex tasks. **Example:** Facial recognition systems
- **Natural Language Processing (NLP):** Algorithms that enable computers to understand, interpret, and generate human language. **Example:** Virtual assistants like Siri or Alexa.
- **Computer Vision:** Algorithms that allow computers to analyze and understand visual information from images or videos. Example: Self-driving cars.
- **Neural Networks:** A type of machine learning model inspired by the human brain, consisting of interconnected nodes that process information and learn patterns. **Example:** Recommendation systems on streaming platforms.

Applications of Artificial Intelligence

1. **GPT (Generative Pre-trained Transformer): an application of Generative AI**
   - A type of large language model capable of generating human-quality text, translating languages, writing different kinds of creative content, and answering your questions in an informative way.
   - **Example:** OpenAI's ChatGPT is a well-known GPT model that can engage in conversations, write different kinds of creative content, and translate languages.
2. **Healthcare**
   - **Disease diagnosis:** AI algorithms can analyze medical images, patient data, and genetic information to assist in diagnosing diseases more accurately and efficiently.
   - **Drug discovery:** AI can accelerate drug discovery by identifying potential drug candidates and simulating their interactions with biological targets.
   - **Personalized medicine:** AI can help tailor treatment plans to individual patients based on their genetic makeup and medical history.

3. Other Sectors

- **Finance:** AI is used for fraud detection, algorithmic trading, and customer service.
- **Manufacturing:** AI-powered robots and automation systems can improve efficiency and productivity in manufacturing processes.
- **Agriculture:** AI can optimize crop yields, monitor soil conditions, and predict weather patterns.
- **Customer service:** AI-powered chatbots can provide 24/7 customer support and answer queries efficiently.
- **Transportation:** AI is used for autonomous vehicles, traffic management, and logistics optimization.

Application	Example
Chatbots	ChatGPT by OpenAI, Copilot by Microsoft Bing
Smart Assistants	Siri, Alexa, Cortana
Recommendation Algorithms	Google's search algorithm, Netflix's personalized content recommendations
Face Recognition	FaceID on iPhones, Security cameras
Navigation Apps	Google Maps, Waze
Social Media Algorithms	Instagram, Facebook, Twitter's curated feeds
Ridesharing Apps	Uber, Ola

AI Action Summit

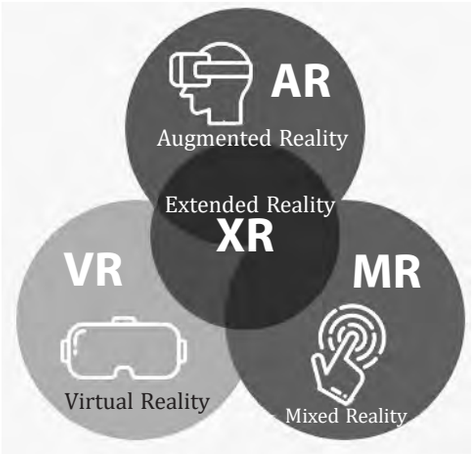
The recent AI Action Summit was held at the Grand Palais in Paris on February 10–11, 2025, and was co-chaired by French President Emmanuel Macron and Indian Prime Minister Narendra Modi. This summit built upon the progress made at the AI Safety Summit held at Bletchley Park in 2023 and the AI Seoul Summit in 2024. While the Paris summit concluded with the adoption of the "Statement on Inclusive and Sustainable Artificial Intelligence for People and the Planet", which was signed by over 60 countries including France, India, China, and members of the European Union, the United States and the United Kingdom did not sign the declaration.

EXTENDED REALITY

Extended Reality (XR) is a broad term that encompasses technologies that enhance or replace our perception of the real world. It includes three primary types: Augmented Reality (AR), Virtual Reality (VR), and Mixed Reality (MR).

1. Augmented Reality (AR)

- **Definition:** AR overlays digital information, such as images, videos, or 3D models, onto the real world.
- **Experience:** Users interact with the real world, enhanced by digital elements.
- **Example:** Pokémon Go, where virtual creatures are superimposed on real-world environments.



2. Virtual Reality (VR)

- **Definition:** VR creates a fully immersive, computer-generated environment that replaces the real world.
- **Experience:** Users are completely immersed in a simulated reality.
- **Example:** VR gaming headsets that transport users to virtual worlds.

3. Mixed Reality (MR)

- **Definition:** MR blends the real and virtual worlds, allowing users to interact with both physical and digital objects.
- **Experience:** A combination of AR and VR, where digital elements seamlessly integrate with the real world.
- **Example: Microsoft HoloLens,** which allows users to interact with holograms superimposed on their real-world surroundings.

Metaverse

The metaverse is a digital realm where individuals can interact with each other and virtual objects in a shared online space.

- Inspired by Neal Stephenson's 1992 novel "Snowcrash," the term envisions a future where people use virtual avatars to participate in a cyberspace world.

Key Elements of the Metaverse:

- **Virtual Reality (VR):** Immersive experiences that replace the real world.
- **Augmented Reality (AR):** Overlays digital information onto the real world.
- **Online Games:** Virtual worlds for gaming and social interactions.
- **Social Media:** Platforms for connecting and interacting with others.

The metaverse aims to create a seamless and immersive experience, blurring the lines between the physical and digital worlds. Companies like Meta (formerly Facebook), Microsoft, and Roblox are investing heavily in this technology, recognizing its potential to drive growth in the technology industry.

ELECTRONICS

Semiconductors

Semiconductors are materials that have electrical conductivity between that of conductors (like metals) and insulators (like glass). Their unique property lies in their ability to control the flow of electric current, making them essential components in various electronic devices. Ex: silicon (Si) and germanium (Ge)

Working:

1. **Doping:** The process of intentionally adding impurities (dopants) to a pure semiconductor material to alter its electrical properties.
   - **N-type semiconductors:** Doped with elements with more valence electrons (e.g., phosphorus) to create an excess of free electrons.
   - **P-type semiconductors:** Doped with elements with fewer valence electrons (e.g., boron) to create "holes" (absence of electrons).

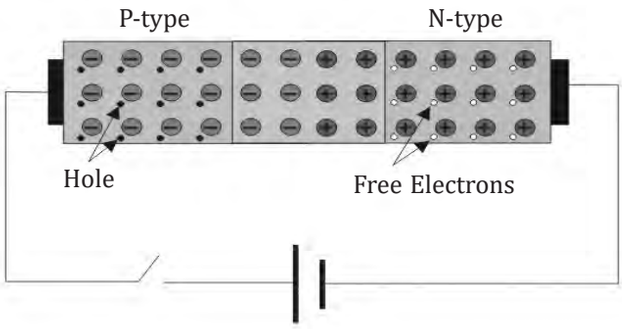


Fig 2.3: Forward Junction p-n Diode

2. **Junctions:** When P-type and N-type semiconductors are joined, a p-n junction is formed. This junction is the basis for many semiconductor devices.
3. **Current Flow:** The application of a voltage across a p-n junction causes current to flow in one direction only, this is called forward **bias**. This principle is a crucial component in diodes, transistors, and other electronic devices.
4. **Difference from Conductors:** In Conductors current can flow in both directions and conductors already have excess electrons to allow current flow unlike semiconductors which need doping with certain elements.

Transistor

A transistor is a semiconductor device with three terminals: emitter, base, and collector. Transistors are the fundamental building blocks of modern electronic circuits from smartphones to smart TVs.

Diode

A diode is a two-terminal semiconductor device that allows current to flow in only one direction. It is often used as a rectifier to convert Alternating Current (AC) into Direct Current (DC). Diodes can also be used as switches, voltage regulators, and Light-Emitting Diodes (LEDs).

Amplifier

An amplifier is a circuit that increases the amplitude of an electrical signal. Transistors are commonly used to build amplifiers, as they can control and amplify the flow of current. Amplifiers are essential components in various electronic devices, such as audio systems, radios, and televisions.

Wireless Charging

Wireless charging eliminates the need for cables by transferring power from a charger to a device using electromagnetic induction.

Working

- **Electromagnetic Induction:** A rapidly changing magnetic field in the charger induces an electric current in the device's receiving coil.
- **Compatibility:** Both the charger and device must support wireless charging.

Types of Wireless Charging

- **Tightly-Coupled Inductive Charging:** Requires close proximity between the charger and device, often using copper coils.
- **Radio Frequency (RF)-Based Charging:** Enables charging at a distance of several feet.
- **Loosely-coupled resonance charging:** Promises charging at even greater distances.

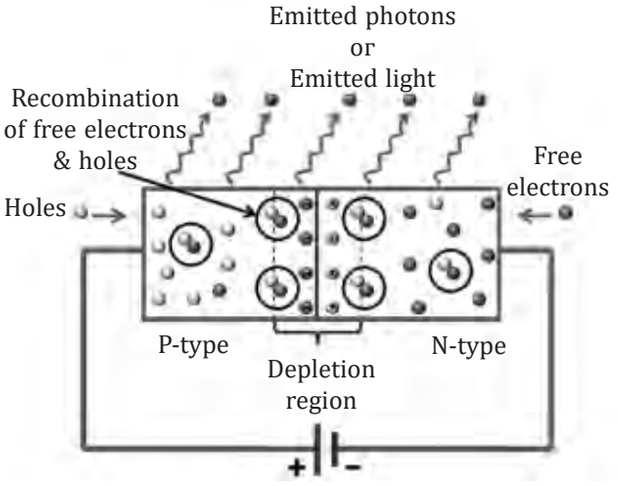
LED (Light-Emitting Diode) (RAS 2013)

Definition: A semiconductor device that emits light when a current is passed through it.

Working: LEDs consist of a p-n junction, where electrons recombine with holes, emitting light.

Applications: Lighting, displays, indicators, and signage.

Working of LED



OLED (Organic Light-Emitting Diode)

Definition: A type of LED that uses organic materials to emit light.

Working: OLEDs emit light when an electric current is applied to a thin layer of organic material.

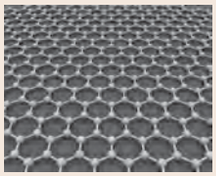
Applications: Displays in smartphones, televisions, and other electronic devices.

Advantages: Deeper blacks, wider viewing angles, and thinner designs compared to traditional LCDs.

Graphene

Graphene, a single layer of carbon atoms in a honeycomb lattice, is the thinnest, strongest, and most conductive material known due to its structure and free-moving electrons.

It combines mechanical strength, thermal and electrical conductivity, flexibility, and lightweight properties. Applications include flexible electronics, batteries, biosensors, water filtration, and composites, with potential in quantum computing and sustainable energy.



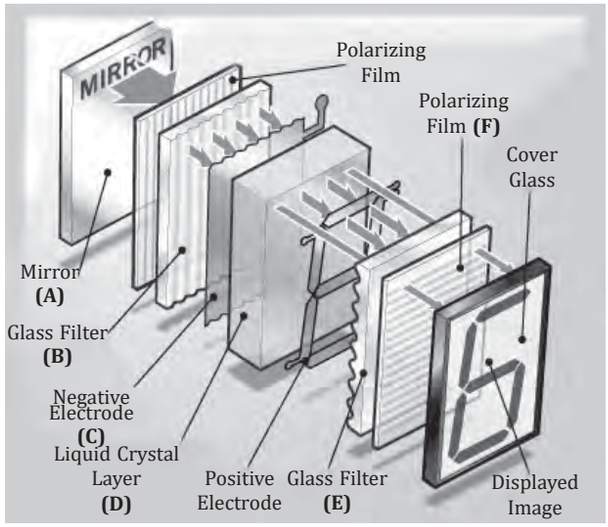
AMOLED (Active-Matrix Organic Light-Emitting Diode)

- **Definition:** An advanced type of OLED that uses a Thin-Film Transistor (TFT) array to control each pixel individually.
- **Working:**
  - **Pixel Structure:** Each pixel in an AMOLED display is composed of multiple organic light-emitting diodes (OLEDs).
  - **Individual Control:** Unlike LCD displays, where pixels are backlit and controlled by a liquid crystal layer, AMOLED displays **allow each pixel to be turned on or off independently.**
  - **Precise Image Control:** This individual control enables AMOLED displays to achieve deeper blacks and more vibrant colors, as pixels that are not being used can be completely turned off, resulting in a higher contrast ratio.
- **Applications:** High-end smartphones, tablets, and televisions.
- **Advantages:** Superior picture quality, higher contrast ratios, and lower power consumption compared to traditional OLEDs.

LCD (Liquid Crystal Displays)

LCD displays, or Liquid Crystal Displays, are commonly found in TVs, computer monitors, and other electronic devices. They work by using liquid crystals to control the amount of light that passes through a screen.

How LCDs Work:



1. **Backlight:** A backlight illuminates the display from behind.
2. **Polarizers:** Two polarizers are placed on opposite sides of the liquid crystal layer.
3. **Liquid Crystals:** These are tiny molecules that can twist and turn when an electric current is applied.
4. **Colour Filters:** A layer of colour filters (red, green, and blue) is placed behind the liquid crystals.

Controlling Light:

- **Off State:** When no voltage is applied to the liquid crystals, they remain twisted. This allows light to pass through both polarizers, creating a bright pixel.
- **On State:** When a voltage is applied, the liquid crystals untwist. This prevents light from passing through the second polarizer, creating a dark pixel.

Creating Images: By controlling the voltage applied to different groups of liquid crystals, the amount of light passing through can be varied. This allows for the creation of different shades of gray and colors, forming images on the screen.

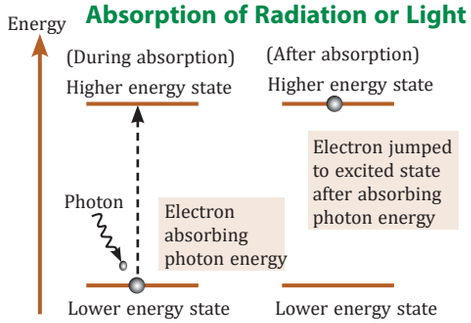
Comparison of LED and LCD

Feature	LED (LED-backlit LCD)	LCD (CCFL-backlit LCD)
Backlighting	Uses Light-Emitting Diodes (LEDs) for backlighting.	Uses Cold Cathode Fluorescent Lamps (CCFLs) for backlighting.
Energy Efficiency	More energy-efficient and consumes less power.	Less energy-efficient and consumes more power.
Brightness	Generally provides higher brightness.	Generally provides lower brightness.
Contrast	Generally offers better contrast and deeper black levels (especially with local dimming).	Generally offers lower contrast and shallower black levels.

Viewing Angle	Viewing angle depends mainly on the LCD panel technology (IPS, VA, TN) rather than the LED backlight.	Viewing angle also depends mainly on the LCD panel technology (IPS, VA, TN).
Response Time	Response time depends primarily on the LCD panel technology; many modern LED-backlit LCDs offer faster response times.	Older CCFL-backlit LCDs generally have slower response times.
Thickness	Thinner and lighter due to LED backlighting.	Thicker and heavier because of CCFL backlighting.
Heat Generation	Produces less heat.	Produces more heat.
Lifespan	Longer lifespan.	Comparatively shorter lifespan.
Environmental Impact	More environmentally friendly and mercury-free.	CCFLs contain small amounts of mercury, making disposal more challenging.
Cost	Generally more expensive (though now widely affordable).	Generally cheaper, but largely obsolete in the consumer market.
Current Usage	Widely used in modern TVs, monitors and laptops.	Mostly found in older display devices.

LASER

LASER stands for Light Amplification by Stimulated Emission of Radiation. It is a technology that produces a highly focused and coherent beam of light.



Key Principles:

- **Stimulated Emission:** Atoms or molecules are excited by external energy, causing them to emit photons with the same energy, phase, and direction.
- **Amplification:** The emitted photons stimulate other atoms to emit photons, leading to a chain reaction and amplification of the light beam.
- **Coherence:** Laser light is highly coherent, meaning the photons are in phase with each other, producing a highly focused beam.

Applications: Communication (Optical fiber communications, barcode scanners); Medicine (Surgery, eye treatments); Industry (Cutting, welding, drilling); Entertainment (holography); spectroscopy.

3D printing

3D printing, or additive manufacturing, creates three-dimensional objects by building layers of material based on a digital model. It works on the **principle of layer-by-layer deposition,** where materials like plastics, metals, or resins are precisely placed using techniques such as fused deposition modeling (FDM), stereolithography (SLA), or selective laser sintering (SLS).

The science behind it involves translating a digital CAD (Computer-Aided Design) file into machine instructions that control the printer's movement and material deposition. Applications span medicine (custom prosthetics, organ models), aerospace (lightweight components), manufacturing (rapid prototyping), construction (3D-printed buildings), and art (custom designs). Its ability to create complex, customizable shapes efficiently is transforming industries globally.

The Evolution and Impact of the Computer

The **20th and 21st centuries** have been defined by a **technological explosion** that has reshaped **human existence**. At the heart of this transformation is the **computer**—arguably one of humanity's most significant inventions. Today, **Information Technology (IT)** is no longer a luxury but a **fundamental utility**, integrated into everything from **healthcare** and **defense** to **education** and **daily household tasks**.

What is a Computer?

In its simplest form, a computer is a sophisticated electronic machine designed to process data. It serves as a dual-purpose tool for **accessing** and **processing** information.

The core logic of computing follows a specific cycle:

1. **Input:** The machine accepts raw data from the external environment.
2. **Processing:** It manipulates that data based on a specific set of instructions known as a **program**.
3. **Output:** It produces new, meaningful information or solutions.

Etymology: The term originates from the English word **"compute,"** which literally means **"to calculate."**

A Brief History of Computing

The journey from manual calculation to high-speed processing is marked by several visionary figures and milestones:

Era/Year	Inventor	Milestone
1642	**Blaise Pascal**	Invented the **Pascalene**, the first mechanical calculator.
1833	**Charles Babbage**	Designed the first automatic calculator. He is widely recognized as the **"Father of Modern Computers."**
1840s	**Lady Ada Augusta**	A student of Babbage who wrote the first computer program in history.
1880	**Herman Hollerith**	Developed an electronic tabulating machine powered by **punch cards**.
1937	**Howard Aiken**	Created **Mark-I**, the first large-scale electromechanical computer.
1946	**J.P. Eckert & John Mauchly**	Invented **ENIAC-I**, the world's first general-purpose electronic computer, utilizing **vacuum tubes**.

The Neumann Revolution

- While many contributed to the hardware, **John von Neumann** provided the conceptual blueprint for modern computing in 1951 with the **EDVAC** (Electronic Discrete Variable Computer). His contributions were twofold and revolutionary:
  - **Stored Program Concept:** The idea that instructions could be stored in the computer's memory alongside data.
  - **Binary System:** The implementation of the 0 and 1 (binary) system as the primary language for computer logic.
- Von Neumann's work is often credited with sparking the "Second Revolution" in computing, directing the industry toward the architecture we still use today.

Branches of Algebra – Quick Revision (RAS 2018)

1. Abstract Algebra
- Deals with abstract algebraic structures rather than ordinary numbers.
- Main structures include Groups, Rings, and Fields.
- Used in advanced mathematics, cryptography, and theoretical computer science.

2. Matrix Algebra
- Studies matrices and their operations.
- A matrix is a rectangular arrangement of numbers, symbols, or expressions in rows and columns.
- Widely used in engineering, computer graphics, and data analysis.

3. Boolean Algebra
- Developed by George Boole.
- Variables take only two values: 0 (False) and 1 (True).
- Based on logical operations: AND, OR, NOT.
- Forms the foundation of digital electronics and computer machine language.

4. Linear Algebra
- Deals with vectors, vector spaces, linear equations, and matrices.
- Used in physics, engineering, computer graphics, machine learning, and data science.
- One of the most important branches of modern mathematics.

Five Generations of Computer

The evolution of **computer technology** is categorized into **five distinct "generations,"** each defined by a major **technological breakthrough** that fundamentally changed how **computers operate**.

These advancements resulted in machines that became **smaller, cheaper, more powerful,** and increasingly **efficient**.

The Five Generations of Computers

Generation	Period	Core Electronic Component	Notable Computer Models
First (I)	1940–1952	**Vacuum Tubes (Electronic Valves)**	EDSAC, EDVAC, UNIVAC-I, ENIAC
Second (II)	1952–1964	**Transistors**	IBM-1401, IBM-1620, CDC-1604, ATLAS
Third (III)	1964–1971	**Integrated Circuits (ICs)**	IBM-360 series, ICL-2903, NCR-395
Fourth (IV)	1971–Present	**Microprocessors (VLSI)**	Apple II, Mits Altair, modern PCs
Fifth (V)	Future/Current	**AI & Optical Fibers**	Supercomputers, Robotics, Quantum computers

Key Evolutionary Milestones

- **First Generation: The Vacuum Tube Era**
  - The earliest computers used **vacuum tubes** for circuitry and **magnetic drums** for memory.
  - These machines were **massive**, often occupying entire rooms, and were incredibly **expensive** to operate.
  - They consumed high levels of **electricity** and generated intense **heat**, which often led to malfunctions.
- **Second Generation: The Transistor Revolution**
  - The invention of the **transistor** replaced bulky vacuum tubes.
  - This was a major **turning point**, as transistors allowed computers to become **smaller, faster,** and more **energy-efficient**.
  - While they still generated considerable heat, they were far more **reliable** than their predecessors.
- **Third Generation: Integrated Circuits (ICs)**
  - During this period, transistors were **miniaturized** and placed on **silicon chips**, called **semiconductors**.
  - This drastically increased the **speed** and **efficiency** of computers.
  - This era also saw the introduction of **keyboards** and **monitors**, replacing punch cards and printouts.
- **Fourth Generation: Microprocessors**
  - The fourth generation was ushered in by **Large Scale Integration (LSI)** and **Very Large Scale Integration (VLSI)**.
  - Thousands of **integrated circuits** were built onto a single **silicon chip** called the **microprocessor**.
  - This technology led to the birth of the **personal computer (PC)**, placing computing power in the hands of individuals.
- **Fifth Generation: Artificial Intelligence & Beyond**
  - The current and future generation focuses on **Artificial Intelligence (AI)** and **Ultra Large Scale Integration (ULSI)**.
  - Using advanced technologies like **optical fibers** and **parallel processing**, these computers aim to simulate human intelligence, recognize voices, and solve complex problems through natural language processing.

Types of Computer

According to size and capacity these are following types of Computer:

- **Microcomputers (Personal Computers)**
  - Designed for **individual use**, these are the most common type of **computer**.
  - Because they are intended for a **single person** at a time, they are widely known as **PCs (Personal Computers)**.
    - **Usage:** Everyday tasks, office work, gaming, and home entertainment.
    - **Examples:** Laptops, desktops, tablets, and smartphones.
- **Minicomputers (Mid-range Servers)**
  - **Minicomputers** sit between **microcomputers** and **mainframes**.
  - They are physically **larger** and boast **5 to 50 times more processing power** than a standard **PC**.
    - **Usage:** Small to medium-sized businesses use them for data management or industrial process control.
- **Mainframe Computers**
  - **Mainframes** are **high-performance machines** designed to handle **massive amounts of data** and **complex computing tasks**.
  - They utilize **Time-Sharing** and **Multi-Tasking** technologies, allowing **over 100 users** to work on different terminals at once.
    - **Usage:** Large institutions like banks, insurance companies, and government agencies use them for bulk data processing.
- **Supercomputers**
  - The **"heavyweights"** of the computing world, **supercomputers** are the **fastest** and most **expensive machines** in existence.
  - They possess **immense storage capacity** and can perform **trillions of calculations per second**.
    - **Usage:** High-level scientific research, weather forecasting, nuclear simulations, and space exploration.
- **Quantum Computers (The Next Frontier)**
  - Currently in the **advanced stages of development**, **Quantum Computers** represent a **paradigm shift**.
  - Unlike traditional computers that use **Binary Bits (0 or 1)**, these machines use **Q-Bits (Quantum Bits)**.
    - **Potential:** They are expected to eventually **surpass the processing capabilities** of the **human brain**, solving problems that are currently **impossible** for even the strongest **supercomputers** to crack.

Comparison

Type	Size	Power/Speed	Typical Users
Micro	Small (Portable)	Standard	Single Individual
Mini	Medium	High	Small Organizations
Mainframe	Large	Very High	100+ Concurrent Users
Super	Massive	Extreme	Scientists/Researchers
Quantum	Experimental	Infinite Potential	Future High-Tech Apps

Key Important Facts Related to Computers

India's Computing Milestones

- **Policy and Education:** India introduced its **New Computer Policy in 1984**. The nation's first private-sector computer university is **Rajiv Gandhi Computer University**.
- **The First Machines:** The first Indian-made computer was named **Siddharth**, manufactured by the Electronics Corporation of India. The very first computer installation in the country took place on **August 16, 1986**, at the Main Post Office in Bangalore.
- **Innovation Hubs:** Bangalore (now Bengaluru) is famously recognized as the **Silicon Valley of India**.
- **Unique Achievements:** India's first pollution-free computerized petrol pump opened in **Mumbai**. Additionally, the Indian Institute of Science developed the **Simputer**, a compact, palm-sized touchscreen device.
- **Supercomputing (C-DAC):** The Centre for Development and Advanced Computing (C-DAC) was founded in Pune in 1988. Under the leadership of **Dr. Vijay P. Bhaskar**, C-DAC developed the **PARAM-10000** in 1998, capable of one billion calculations per second. Earlier, National Aeronautics Laboratories in Bangalore developed the **FLO SOLVER** supercomputer.

Digital Firsts in India

- **Newspaper:** The Hindu was the first Indian newspaper available online.
- **Magazine:** India Today was the first Indian magazine to go digital.
- **Politics:** The **Bhartiya Janata Party (BJP)** was the first Indian political party to launch its own website.

Global Hardware and Software Landmarks

- **Operating Systems: Windows** remains the most popular operating system worldwide.
- **Hardware Icons:** The **CRAY K-1-S** (USA) was the world's first supercomputer. **ENIAC** stands as the world's first electronic digital computer, while **UNIVAC** was the first practical digital computer.
- **Consumer Tech:** The **Commodore VIC/20** was the first home computer. **IBM** (International Business Machine) is the primary American giant in the industry.
- **Components: J.S. Kilby** is credited with developing Integrated Circuit (IC) chips.
- **Peripherals: Laser printers** are categorized as the fastest printing devices. **Modems** allow computers to communicate over telephone lines.

Notable Terminology and Concepts

- **Computer Literacy Day:** Observed annually on **December 2**.
- **Computer Categories:** Computers are primarily classified into three types: **Digital, Analog, and Hybrid**.
- **Bugs and Viruses:** A computer error is technically called a **"Bug."** A **virus** is a man-made digital parasite designed to infect and corrupt files.
- **The Y2K Issue:** Known as the **"Millennium Bug,"** this was a technical calendar-related problem concerning the transition to the year 2000.
- **USENET:** A networking link established to connect various universities.

Literature and Intelligence

- **The Chess Defeat:** The supercomputer **Deep Blue** famously defeated World Champion Garry Kasparov; it could process 200 million chess positions per second.
- **Books: Tracy Kidder** authored the first book on personal computers. His work, The Soul of a New Machine, earned a **Pulitzer Prize**.
- **Journalism:** Computer and Automation was the first-ever computer magazine.

Supercomputing

Supercomputing has come a long way since the early days of **CRAY** and **Deep Blue**.

While these machines are **iconic** and historically significant, the landscape of **2026** is dominated by **Exascale Computing** systems capable of performing **quintillions of calculations per second**.

Historically Significant Supercomputers

Name	Manufacturer	Significance
CRAY K-1-S	Cray Research, USA	A variant of the Cray-1; the first to successfully use **vector processing** and a "C" shape to shorten wiring.
Deep Blue	IBM, USA	Famous for being the first computer to **defeat a World Chess Champion** (Garry Kasparov) in 1997.
Blue Gene	IBM, USA	A series of supercomputers designed to reach operating speeds in the **petaflops** range, primarily for life sciences.
COSMOS	Cambridge, UK	A series of systems used largely for **cosmological research** and theoretical physics, often involving Stephen Hawking's work.

World Leaders in 2026 (The Exascale Era)

Today, the most powerful systems are ranked by their ability to perform **Floating Point Operations Per Second (FLOPS)**.

Rank	Name	Manufacturer	Performance	Country
1	**El Capitan**	HPE / AMD	**1.8+ ExaFLOPS**	USA
2	**Frontier**	HPE / AMD	**1.2+ ExaFLOPS**	USA
3	**Aurora**	Intel / HPE	**1.0+ ExaFLOPS**	USA
4	**Eagle**	Microsoft / NVIDIA	**560+ PetaFLOPS**	USA (Cloud)
5	**HPC6**	HPE / NVIDIA	**470+ PetaFLOPS**	Italy

Key Technological Shifts

- **Exascale Barrier:** In 2026, we have firmly entered the exascale era, where machines like **El Capitan** perform over 10^{18} calculations per second.
- **AI Integration:** Modern supercomputers like **Eagle** are specifically built for training massive AI models, utilizing thousands of interconnected GPUs.
- **Efficiency:** There is now a heavy focus on "Green" supercomputing, measuring performance per watt to manage the immense power consumption of these facilities.

India's Supercomputing Development

India has built several indigenous supercomputers through specialized research and academic institutions.

Name	Manufacturer / Organization
FLO SOLVER	National Aeronautics Laboratory (NAL), Bangalore
PACE	Defense Research and Development Organization (DRDO)
PARAM-10000	C-DAC, Pune
CHIPP-16	C-Dot, Bangalore
MULTIMICRO	Indian Institute of Science (IISc), Bangalore
MACH	Indian Institute of Technology (IIT), Bombay

AIRAWAT

- The **Centre for Development of Advanced Computing (C-DAC)** has implemented the **AI Research Analytics and Knowledge Dissemination Platform (AIRAWAT)**, a **200 AI Petaflops** supercomputing facility, at C-DAC, Pune under the initiative of the **Ministry of Electronics and Information Technology (MeitY), Government of India**.
- AIRAWAT is designed to support advanced research in **Artificial Intelligence (AI)**, Machine Learning (ML), Big Data Analytics, and related emerging technologies.
- AIRAWAT was ranked **75th globally** in the **61st edition of the Top500 Global Supercomputing List**, announced at the **International Supercomputing Conference (ISC 2023)** held in Germany.

- This achievement strengthened India's position among the leading nations in the field of **AI supercomputing** and high-performance computing infrastructure.

Key Indian Landmarks

- **Computerarium:** The first of its kind in India is located in **Bengaluru, Karnataka**.
- **Computerized Village: Vellanad**, in the Thiruvananthapuram district of Kerala, is the nation's first fully computerized village.

Microcomputers and Operating Systems

Devices such as **Personal Computers (PCs)**, **home computers**, and **electronic notebooks** are classified as **microcomputers**. These machines utilize various **Operating Systems (OS)** to function, including:

- **Apple:** Mac OS
- **Microsoft/IBM:** DOS, Pro DOS, MS-DOS, PC-DOS, Windows
- **Others:** CP/M, XENIX, LINUX

The Impact of Linus Torvalds

Linus Benedict Torvalds, born in Helsinki, Finland on December 28, 1969, is the creator of the Unix-like **Linux** Operating System.

- **Version 1.0:** Completed on **September 17, 1991**.
- **Open Source:** By releasing Linux under the **General Public License**, Torvalds made the software free and accessible to everyone.
- **Significance:** His advocacy for free software fundamentally transformed the global software market.

Computer Fundamentals

A computer is used to manage mechanical actions and consists of two primary divisions:

1. **Hardware:** The physical "body" of the computer—units you can touch that coordinate to solve problems.
2. **Software:** The "mind" or instructional programs that tell the hardware exactly what to perform.

The Binary Foundation (Machine Language)

The Nature of Machine Language

- **The Electrical Basis:** Computers are essentially complex systems of electrical switches that do not inherently understand human language or abstract mathematics.
- **Voltage Representation:** Information is communicated through voltage levels, where **0 (Low State)** typically indicates 0 volts and **1 (High State)** indicates approximately 5 volts.
- **The Bit:** Known as a **"Binary Digit,"** a bit is the smallest unit of data in computing, representing a single choice between two electrical states.
  - **Byte:** A combination of **8 bits**. With 8 bits, there are 2^8 or **256 possible combinations**, which is plenty to represent all letters, numbers, and special symbols (like $, @, or ₹).
  - **Scaling Up:** To handle larger sets of data, we use higher denominations:
    - **Kilobyte (KB):** Historically 2^{10} (1024) bytes.
    - **Megabyte (MB):** Approximately 1 million bytes.
    - **Gigabyte (GB):** Approximately 1 billion bytes.
- **Data Width:** This refers to how many bits a computer can process simultaneously. While early machines handled 8 bits at a time, modern systems operate with 16, 32, or 64-bit widths.

Units of Data Measurement

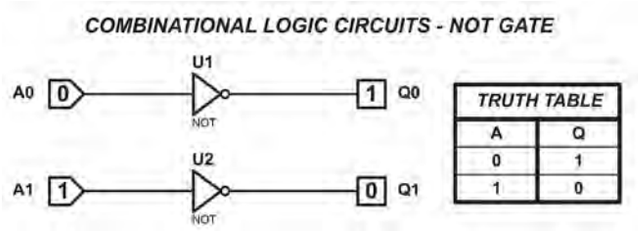
Computers process information in **binary**, and as data volume grows, we use specific **units** to measure its size. This hierarchy scales from the **smallest possible unit** a single **bit** to massive storage capacities like **Petabytes**.

Data Measurement Conversion Table (RAS 2023/2013)

Data Size	Equivalent Unit	Common Context
1 Bit	Binary Digit (0 or 1)	The smallest unit of data.
4 Bits	**1 Nibble**	Half of a byte.
8 Bits (2 Nibbles)	**1 Byte**	A single character (e.g., 'A' or '$').
1024 Bytes	**1 Kilobyte (KB)**	A short text document.
1024 KB	**1 Megabyte (MB)**	A high-quality photo or a small song file.
1024 MB	**1 Gigabyte (GB)**	A high-definition movie.
1024 GB	**1 Terabyte (TB)**	The capacity of a modern hard drive.
1024 TB	**1 Petabyte (PB)**	Massive server farms or large-scale data centers.

Logic Gates and Processing

- **Definition:** Logic gates are the physical realization of Boolean algebra, acting as the internal circuitry that processes electrical inputs to determine a specific output.
- **Fundamental Gates:**
  - **NOT Gate:** This gate acts as an inverter, switching a 1 to a 0 or vice versa.
  - **AND Gate:** This gate only produces a high output (1) if all its inputs are high (1).
  - **OR Gate:** This gate produces a high output (1) if at least one of its inputs is high (1).
- **Complexity through Combination:** By combining these basic gates, engineers can create complex circuits capable of performing addition, subtraction, and advanced data routing.



Physical Hardware Components

- **Flip-Flops:** These are the primary **bistable devices** that can remain in one of **two states**, allowing them to **"remember" a single bit** of information even after the initial signal changes.
- **Registers:** Registers are **high-speed storage locations** within the **CPU**, composed of multiple **flip-flops**, used to hold data that is being actively processed.
- **Integrated Circuits (IC):** An **IC** is a collection of microscopic **electronic circuits** including **transistors** and **resistors** etched onto a thin slice of **semiconductor material**, usually **silicon**.
- **Role of Semiconductors: Silicon** is used because its **electrical conductivity** can be precisely controlled, allowing it to act as either a **conductor** or an **insulator** to create electronic switches.

COMPUTER HARDWARE

Computer hardware consists of the **physical units** that coordinate to solve problems through specific operations. These components are structured into three primary categories: **Input**, **Processing**, and **Output units**.

Core Organization: Every computer system is organized into three functional pillars:

Central Processing Unit (CPU)

- The **CPU** is the part of a computer that performs the main function of **information processing**. The **memory unit** stores data, while the computer supplies processed information back to users through special **output devices**.
- The **Central Processing Unit (CPU)** is the most important part of the computer and is often called the **"brain of the computer."** It performs all the required **calculations** and **data processing** operations.
- The CPU can be divided into three main components: **(a) ALU, (b) CU and (c) Registers**
  - **Arithmetic and Logic Unit (ALU)**
    - The **ALU** performs all the **mathematical** and **logical operations** on the information supplied to the CPU.
  - **Control Unit (CU)**
    - The **Control Unit (CU)** directs the working of the CPU.
    - It fetches **instructions (programs)** from memory and controls the **flow of data** between the ALU and other parts of the computer according to those instructions.
  - **Registers**
    - **Registers** are **storage locations** that hold instructions or data while the CPU is using them.
    - They consist of **flip-flops** and are the **fastest memory elements** in a computer.
    - In contrast, the **memory unit** stores instructions and data before or after they are processed by the CPU.
- **Main attributes of CPU**
  - **Data Width**
    - **Data Width** refers to the number of **bits of data** that can be manipulated within the **CPU** at a given time. It is also called the computer's **word size**.
    - Computers generally have data widths ranging from **8 to 64 bits**. A **higher data width** enables the CPU to process data **faster**, making the computer more **powerful**.
  - **Address Range**
    - **Address Range** refers to the amount of **memory** that can be directly **read** or **written** by the CPU.
  - **Clock Speed**
    - The speed of the **CPU** is known as **Clock Speed**. A computer is made up of tiny electronic devices that can be switched **on** or **off** to represent **1** or **0**.
    - At any moment, thousands of such devices change their state. To synchronize these changes, the CPU uses an **internal clock**. With every **tick** of this clock, all required switches change their positions in perfect harmony.

- The greater the number of **ticks per second**, the **faster** the CPU operates. Clock speed is measured in **Megahertz (MHz)** and **Gigahertz (GHz)**.

- **Hertz (Hz)** is a unit of **frequency**.
- **1 MHz = 1 million ticks per second**
- **1 GHz = 1000 MHz**
  - A **higher clock speed** results in a **faster computer**.

Types of CPU (Based on Cores) (RAS 2013)

- Single-Core
- Dual-Core
- Quad-Core
- Hexa-Core (6 Cores)
- Octa-Core (8 Cores)
- Deca-Core (10 Cores)

Major Processor Series

Celeron

- Entry-level processor.
- Designed for low power consumption and low cost.

Pentium

- Popular processor series.
- Widely used in personal computers during the late 1990s.

Core

- Intel's high-performance processor series.
- Offers better speed, efficiency, and multitasking performance.

Examples

- Intel Celeron
- Intel Pentium
- Intel Core (Core i3, i5, i7, i9)

Memory Unit (MU)

The **Memory Unit (MU)** stores all **instructions** and **data** required by the **CPU**. It is an important part of the computer system. The storage device of a computer system is known as **memory**.

The Memory Unit can **receive data**, **store it**, and deliver it according to the instructions from the **Control Unit (CU)**.

Memory is of two kinds: **Primary Memory and Secondary Memory**

- **Primary Memory**
  - **Primary Memory** is often referred to as the **working memory** or **main memory** of a computer system.
  - It can send and receive data at a very **high speed**. It is **temporary** in nature, meaning the stored data is lost when the computer is switched off.
  - Therefore, it is also called **volatile memory**. An example of primary memory is **RAM**.
  - Primary memory is **directly accessible** to the CPU and must provide data very quickly.
  - The two main types of primary memory are: **Random Access Memory (RAM) and Read Only Memory (ROM)**
  - **Random Access Memory (RAM)**
    - **RAM** is a **read/write memory**. The CPU can change the contents of RAM at any time. RAM is also **volatile**, meaning its data is erased when power is turned off.
    - The **capacity of RAM** greatly influences the computing ability of a computer and is usually measured in **Kilobytes (KB)** and **Megabytes (MB)**.
  - **Read Only Memory (ROM)**
    - **ROM** cannot be altered easily. Information is stored in ROM during the **manufacturing process**. This information usually contains crucial instructions required for the basic functioning of the computer.
    - ROM is **non-volatile**, meaning it retains information even after the power is turned off.
    - **Programmable Read Only Memory (PROM)**
- **PROM** is a type of ROM that can be **programmed** by the manufacturer. A company may load specific programs into PROM, after which it functions like a normal ROM.
- **Secondary Memory**
- **Secondary Memory** is used for **long-term storage** of data. It operates at a much **slower speed** than primary memory.
- Since the stored data remains even after power is turned off, it is called **non-volatile memory**.
- It is also **cheaper** than primary memory.
- Examples of secondary memory include:
  - **Floppy Disks**
  - **Hard Disks**
  - **Magnetic Tapes**
  - **Compact Disks (CDs)**
- Primary memory is fast but expensive, so computers use secondary memory to reduce storage costs.
- Secondary memory is **not directly accessible** to the CPU.
- Data must first be transferred to **primary memory** and then processed by the CPU.
- **Floppy Diskette**
  - A **floppy diskette** is a plastic disk coated with **magnetic material**.
  - Special devices called **disk drives** read from and write to floppy disks using magnetic heads.

- Information stored on a floppy disk can be **directly accessed**.

- **Magnetic Tape**
  - **Magnetic tapes** are long plastic tapes coated with magnetic material.
  - They can store much larger amounts of data than floppy disks.
  - However, information on magnetic tapes cannot be accessed directly and must be searched sequentially.
- **Hard Disk**
  - A **hard disk** works similarly to a floppy disk but contains several hard material disks inside one drive.
  - Hard disks provide much greater **storage capacity** and **speed**.
- **Compact Disk (CD)**
  - A **Compact Disk (CD)** is an **optical storage medium**.
  - Unlike magnetic storage devices, CDs use the **properties of light** for reading data.
  - CDs are made of special plastic and are read using a **laser beam**.
  - Although **secondary memory** is much **slower** than primary memory, it is highly useful because it is **non-volatile** and can store information for **long periods of time**.

The Interface of Computing: Input, Output, and Instructions

To interact with a **computer**, there must be physical channels that allow **humans** and **machines** to exchange data. These tools, known as **peripheral devices**, sit on the **"periphery"** of the **Central Processing Unit (CPU)** and act as an **interface**, translating human actions into **machine-readable code** and vice versa.

Input Units: Supplying Data

Input devices allow us to enter information into the system. While the **keyboard** and **mouse** are the most universal, several specialized devices serve specific industries:

- **Keyboard & Mouse:** Primary tools for **typing** and **navigation**. The mouse is a **pointing device** that controls the **on-screen cursor** through physical movement.
- **Optical Mark Reader (OMR):** Detects marks made by **pens** or **pencils** on special forms. Commonly used in **competitive examinations** and surveys.
- **Magnetic Ink Character Reader (MICR):** Used mainly by **banks** to read characters printed in **magnetic ink** on cheques.
- **Bar Code Reader:** Uses **light scanning** to read vertical lines representing **binary data** such as product price and expiry date.
- **Digital Camera:** Uses **light-sensitive circuitry** to capture and input **visual data** into the computer system.

Output Units: Conveying Results

- Devices that display or produce the **results** of computer processing. Common examples include **monitors** and **printers**.
- **Visual Display Unit (VDU)**
  - Commonly known as a **monitor**.
  - Traditionally used **Cathode Ray Tubes (CRT)** to display information.
  - Images and characters are formed using tiny dots called **pixels (picture elements)**.
- **Printers**
- Printers transfer **digital characters** onto physical media such as **paper**.
- Main types of printers include:
  - **Dot Matrix Printer:** Forms characters using patterns of tiny **dots** created by physical pins.
  - **Ink-jet Printer:** Sprays streams of **ink** to produce smooth and high-quality printing.
  - **Laser Printer:** Uses a **laser beam** to precisely fuse characters onto the page.
- **Speaker:** Produces **audio output** such as music, voice, and alerts.
- **Headphones:** Provide personal **audio output** for listening privately.
- **Projector:** Projects computer-generated images and videos onto a large screen or wall.
- **Plotter:** Used for printing large and highly precise graphics such as **maps**, **engineering drawings**, and **architectural designs**.
- **Braille Reader / Braille Printer:** Special output devices designed for **visually impaired users**.
- **LED / LCD Display Panels:** Modern flat-panel display devices used in computers and digital systems.

Software and Execution

- **Hardware alone** cannot function without a **program**, which is a detailed sequence of **instructions** that tells the **CPU** how to process data.
- **Storage & RAM:** Programs are usually stored in **secondary memory** such as a **hard drive** and are transferred to **RAM (Random Access Memory)** when needed for use.
- **Execution:** Execution is the process in which the **CPU** processes and moves data according to the program's **instructions**.

❖ **Programming Languages:** Programs are written using specialized **programming languages**, each following a specific set of grammatical rules known as **syntax**.

Modem (RAS 2013)

❖ Modem = Modulator + Demodulator
❖ A modem is a hardware device that converts digital signals into analog signals and analog signals back into digital signals.
❖ It enables data transmission through telephone lines, coaxial cables, and other communication media.

Functions

❖ Performs Modulation (Digital → Analog).
❖ Performs Demodulation (Analog → Digital).
❖ Facilitates Internet and data communication.

Types of Computer Modems

1. Onboard Modem

❖ Built directly onto the computer motherboard.

2. Internal Modem

❖ Installed inside a desktop computer.
❖ Connects through a PCI slot (modern PCs) or ISA slot (older PCs).

3. External Modem

❖ A separate device connected externally via a Serial Port or USB Port.

4. Removable Modem

❖ Used in older laptops.
❖ Fits into a PCMCIA slot and can be added or removed as needed.

PROGRAMMING LANGUAGES

❖ A **programming language** is a **formal set of instructions** used to communicate with a **computer**. Since computers do not understand **human languages** like **English** or **Hindi** and instead operate using **binary (0s and 1s)**, programming languages act as a **bridge**.
❖ They allow humans to write **code** in a way that is relatively **easy to read**, which is then translated into **machine-readable code** that a computer's **processor** can execute.
❖ **Programming languages** have evolved through **distinct stages**, advancing from **early mathematical notations** to sophisticated tools for **artificial intelligence**.

Generation	Period	Representative Languages
First (1st)	1940–1952	FORTRAN-I
Second (2nd)	1952–1964	FORTRAN-II, ALGOL-60, COBOL, LISP
Third (3rd)	1964–1971	PL/I, ALGOL-W, ALGOL-68, Pascal, SIMULA-67, APL, SNOBOL-4, BASIC, C
Fourth (4th)	1971–Present	CLUE, ALFARD, UCLID, Reformed Pascal, MODULA, EDA, ORACLE
Fifth (5th)	Future	Artificial Intelligence Languages

Categories of Programming Languages

❖ Programming languages are classified according to how closely they relate to **machine language**.
❖ **Low-Level Languages**
  ➢ Closer to the **computer hardware**.
  ➢ Provide direct control over the system.
  ➢ Difficult for humans to read and write.
  ➢ **Machine Language**
    ◆ The most basic language of computers.
    ◆ Written entirely in **binary digits (0s and 1s)**.
    ◆ Directly understood by the CPU.
    ◆ Very fast but difficult to program.
  ➢ **Assembly Language**
    ◆ Uses short mnemonic codes such as **ADD, MOV, SUB**.
    ◆ Easier than machine language.
    ◆ Requires an **Assembler** to convert code into binary.
    ◆ Hardware dependent.
❖ **High-Level Languages**
❖ Designed to be **human-readable**.
❖ Use English-like words and mathematical symbols.
❖ Easier to learn, write, debug, and maintain.
❖ Need translation into machine language before execution.
❖ **Examples of High-Level Languages**
  ➢ **C & C++:** Used in system software and game development.
  ➢ **JAVA:** Famous for "**Write Once, Run Anywhere**."
  ➢ **Fortran:** Used for scientific and engineering calculations.
  ➢ **Pascal:** Used for teaching structured programming.

TRANSLATION PROGRAMS

Since computers understand only machine language, translation tools are required.

❖ **Assembler**
  ➢ Converts **Assembly Language** into **Machine Code**.

- Performs **1-to-1 translation** of mnemonic instructions into binary.
- Used only for assembly programs.
- **Typical Language**
  - Assembly Language

- **Compiler**
  - Translates the **entire program at once** into machine code.
  - Produces an executable file such as **.exe**.
  - The compiled program can run without the compiler.
  - **Features**
    - Faster execution
    - Detects errors after scanning the complete program
  - **Typical Languages**
    - C, C++, Pascal, Fortran
- **Interpreter**
  - Translates and executes code **line-by-line**.
  - Stops immediately if an error is found.
  - Interpreter must be present whenever the program runs.
  - **Features**
    - Easier debugging
    - Slower execution compared to compiler
  - **Typical Languages**
    - Python, JavaScript, Ruby

Important Points

- **Machine Language** is the only language directly understood by computers.
- **Assembly Language** requires an **Assembler**.
- **High-Level Languages** require a **Compiler** or **Interpreter**.
- The final output of every program is always converted into **Binary Code**.
- High-level languages are more **portable** than low-level languages.

SOFTWARE

- **Software** is a collection of organized **programs**, instructions, and related data that directs a computer to perform specific tasks.
- It acts as the controlling force behind the computer's **hardware components**.
- While **hardware** refers to the physical and tangible parts of a computer, software provides the **instructions** that make the hardware operational.
- Without software, hardware cannot perform any meaningful operation.
- Software is **intangible** in nature and cannot be physically touched.
- It acts as a bridge between the **user** and the **computer hardware**.
- Software is developed using different **programming languages** such as C, C++, Java, Python, and others.

CATEGORIES OF SOFTWARE

Application Software

- **Application software** consists of programs designed to help users perform **specific tasks**.
- It transforms the computer into a specialized tool for solving user-oriented problems.
- Application software is generally user-friendly and interactive.
- It depends on **system software** for execution.
- **Types of Application Software**
  - **Word Processing Software**
    - Word processors are programs used for creating, editing, formatting, and printing documents.
    - They are commonly used in schools, offices, and businesses.
    - Features include spell checking, grammar correction, text formatting, and page layout design.
    - **Examples:** Microsoft Word, Google Docs, LibreOffice Writer, WordPad, WPS Writer etc.
  - **Database Management Systems (DBMS)**
    - A **DBMS** is software used to store, organize, manage, and retrieve large amounts of **data** efficiently.
    - It helps maintain records systematically.
    - DBMS is widely used in banks, hospitals, schools, railways, and government offices.
    - **Examples:** MySQL, Oracle, MS Access, PostgreSQL, MongoDB, SQLite etc.
  - **Spreadsheet Software**
    - Spreadsheet software is used for calculations, budgeting, accounting, and data analysis.
    - It organizes information in the form of rows and columns.
    - It also supports charts, graphs, and formulas.
    - **Examples:** Microsoft Excel, Google Sheets, LibreOffice Calc, Lotus 1-2-3, Apple Numbers etc.
  - **Presentation Software**
    - Presentation software is used to create slideshows and visual presentations.
    - It is widely used in business meetings, teaching, and seminars.

- **Examples:** Microsoft PowerPoint, Google Slides, Apple Keynote, LibreOffice Impress, Prezi etc.

➢ **Web Browsers**
- Web browsers are software applications used to access and browse the **internet**.
- They help users search information, open websites, and use online services.
- **Examples:** Google Chrome, Mozilla Firefox, Microsoft Edge, Safari, Opera, Brave Browser etc.

➢ **Media Players**
- Media players are used to play **audio** and **video** files.
- They support multimedia entertainment and content management.
- **Examples:**VLC Media Player, Windows Media Player, KMPlayer, GOM Player, QuickTime Player

➢ **Graphic and Design Software**
- These programs are used for image editing, drawing, animation, and graphic designing.
- They are commonly used by designers, photographers, and artists.
- **Examples:** Adobe Photoshop, CorelDRAW, Adobe Illustrator, Canva GIMP, AutoCA

➢ **Accounting Software**
- Accounting software is used for managing financial records, billing, payroll, and taxation.
- **Examples**: Tally QuickBooks, Zoho Books, Busy Accounting Software

➢ **Educational Software**
- Educational software is designed for learning and teaching purposes.
- It helps students improve skills through interactive learning methods.
- **Examples:** BYJU'S Duolingo, Google Classroom, Khan Academy

➢ **Communication Software**
- Communication software enables users to exchange messages, audio, video, and files over networks.
- **Examples**: Zoom, Microsoft Teams, Skype, WhatsApp, Telegram

SYSTEM SOFTWARE

❖ **System software** controls and manages the internal operations of the computer.

❖ It provides a platform on which **application software** runs.

❖ It manages hardware resources such as the CPU, memory, and input-output devices.

❖ System software mainly works in the background.

❖ **Types of System Software**

❖ **Operating System (OS)**

➢ The **Operating System** is the most important type of system software.

➢ It acts as an intermediary between the **user**, **application software**, and the **hardware**.

➢ It controls and coordinates all computer activities.

➢ **Functions of Operating System**
- Manages hardware resources
- Controls CPU operations
- Manages memory allocation
- Handles file management
- Controls input and output devices
- Provides security
- Supports multitasking

➢ **Examples**: Windows, Mac OS, Linux, Unix, Android, iOS, MS-DOS

❖ **Utility Software**

➢ Utility software helps maintain, protect, and optimize computer performance.

➢ **Functions**
- Virus protection
- File compression
- Disk cleanup
- Data backup
- System optimization

➢ **Examples**
- **Antivirus Software:** Quick Heal Norton McAfee Avast
- **Compression Tools:** WinZip WinRAR 7-Zip
- **Disk Utilities:** Disk Cleanup Defragmenter

❖ **Language Translators**

➢ Language translators convert programming languages into **machine-readable code**.

➢ **Types**
- **Assembler:** Converts assembly language into machine language.
- **Compiler:** Translates the entire program at once.
- **Interpreter:** Translates and executes code line-by-line.

➢ **Examples:** GCC Compiler, Python Interpreter, Java Compiler

❖ **Device Drivers**

➢ Device drivers are software programs that help the operating system communicate with hardware devices.

➢ **Examples**: Printer Driver, Graphics Driver, Audio Driver, Keyboard Driver, Wi-Fi Driver

Android operating system (RAS 2016)

1. Android Jelly Bean (v4.1 / v4.2)

- **Release Date:** Launched in June 2012.
- **Predecessor:** Served as the successor to Android Ice Cream Sandwich.
- **Target Devices:** Designed for mobile phones, tablet PCs, and supported handheld devices.

2. Android KitKat (v4.4)

- **Target Devices:** Built for smartphones and tablets.
- **Memory Optimization:** Uses advanced technology to optimize memory allocation.
- **Low RAM Compatibility:** Runs smoothly on devices with as little as 512 MB of RAM.
- **Significance:** Eliminated the high internal memory requirements of older versions, making it compatible with older device models.

3. Android Lollipop (v5.0)

- **Release Date:** Debuted in November 2014.
- **Predecessor:** Launched as the direct successor to Android KitKat.
- **Naming:** Uses the traditional dessert-themed codename convention.

4. Android Marshmallow (v6.0)

- **Version Milestones:** The 6th major edition and 13th version of the Android OS (codenamed "Android M" during development).

Release Timeline: Released as a beta build on May 28, 2015, and publicly launched on October 5, 2015.

- **Rollout:** Google Nexus devices were the first to receive this update.
- **Primary Focus:** Centered on enhancing and refining the overall user experience introduced by Lollipop.

DIFFERENCE BETWEEN APPLICATION SOFTWARE AND SYSTEM SOFTWARE

Basis	Application Software	System Software
Purpose	Performs specific user tasks	Manages computer operations
Interaction	Direct interaction with users	Mostly works in background
Dependency	Depends on system software	Independent of application software
Examples	MS Word, Excel, Chrome	Windows, Linux, Android

Important Keyboard Shortcuts (Commands)

Text Formatting & Alignment

Shortcut	Action
Ctrl + B	Bold
Ctrl + I	Italics
Ctrl + U	Underline
Ctrl + D	Open Font Dialogue Box
Ctrl + K	Insert Hyperlink
Ctrl + E	Centre Alignment
Ctrl + L	Left Alignment
Ctrl + R	Right Alignment
Ctrl + J	Justified Alignment

Essential Editing (The "Big Five")

Shortcut	Action
Ctrl + A	Select All
Ctrl + C	Copy
Ctrl + X	Cut
Ctrl + V	**Paste**
Ctrl + Z	Undo
Ctrl + Y	Redo

File Management

Shortcut	Action
Ctrl + N	Open New blank document
Ctrl + O	Open existing document
Ctrl + S	Save
F12	Save As
Ctrl + W	Close File
Ctrl + P	Print
Ctrl + F2	Print Preview

System & Program Navigation

Shortcut	Action
Alt + Tab	Switch to next opened program
Alt + Shift + Tab	Switch to previous opened program
Win + D	Show/Hide Desktop
Win + E	Open File Explorer
Win + L	Lock your Computer
Alt + F4	Close active window / Shut down
Ctrl + Shift + Esc	Open Task Manager
PrtScn	Take a screen shot
ESC	Escape / Cancel

Function Key Commands (F1 - F12)

Shortcut	Action
F1	Help
F2	Rename a file or Edit a cell
F4	Show Properties (or repeat last action in Office)
F5	Refresh page / Go to
F7	Spell Check
F11	Toggle Full Screen

Document & Cursor Navigation

Shortcut	Action
Ctrl + Home	Go to beginning of a File / Worksheet
Ctrl + End	Go to end of a File / Worksheet
Ctrl + F	Find (Search for text)
Ctrl + H	Find and Replace
Ctrl + ← / →	Move cursor one whole word at a time
Ctrl + Backspace	Delete one whole word at a time
Shift + Arrows	Highlight/Select text

Web Browser Specials

Shortcut	Action
Ctrl + T	Open a new tab
Ctrl + Shift + T	Reopen the last closed tab
Ctrl + L	Highlight the address bar
Ctrl + (+) / (-)	Zoom in or out

Artifical Intelligence

Fourth AI Impact Summit 2026: New Delhi

- **Time:** 16-20 February, 2026.
- **Location:** Bharat Mandapam, New Delhi.
- **Importance:** This is the **first global AI conference** to be organized in the Global South.
- **Theme:** "Sarvajan Hitay, Sarvajan Sukhay" (For the good of all, for the happiness of all).
- **Key Formula:** People, Planet and Progress.
- **Timeline of AI Summit Development:**
  - **Bletchley Park (UK), 2023:** First 'AI Safety Summit' - **Bletchley Declaration** (Focused on AI safety risks).
  - **Seoul (South Korea), 2024:** Emphasis on innovation and inclusion along with safety.
  - **Paris (France), 2025:** Focus on practical implementation and economic opportunities.
  - **New Delhi (India), 2026:** AI Impact Summit (India as a democratizer and service provider).
- **3 Main Goals of the Conference:**
  - **Empowerment:** Effective use of AI to promote innovation.
  - **Global Hub:** Establishing India as a major 'AI service provider' for the entire world.
  - **Democratization:** Ensuring equal access for all to compute capacity, datasets, and algorithms.
- **Key Objectives:**
  - **Economic Growth:** Harnessing and scaling AI technologies directly for job creation and sustainable economic development.
  - **Inclusive Governance:** Establishing standardized, global benchmarks to govern responsible and safe AI deployments.
  - **Public Service Enhancement:** Actively promoting and integrating AI applications across healthcare, education, and municipal/urban governance architectures.
  - **Resource Equality:** Ensuring equal, unobstructed access to state-of-the-art technological resources, with a specific focus on bridging gaps for developing countries.

Quantum Technology

Quantum Laboratories

- The Government of India has approved the establishment of **Quantum Laboratories in 23 institutions** under the National Quantum Mission.
- **Introduction:** Quantum Laboratories are specialized centers where education, training, and research in quantum technologies will be promoted.
- **Capacity Building:** Their objective is to develop skilled human resources in fields such as quantum computing, communication, and sensing.
- **Research and Innovation:** These laboratories will encourage indigenous research and innovation in cutting-edge technologies like quantum cryptography and advanced materials.

Quantum Valley Project

- India is developing **Amaravati (Andhra Pradesh)** as a strategic center to expand its quantum capabilities.
- Recently, the foundation stone for the **'Quantum Valley'** project was laid in Amaravati, Andhra Pradesh.
- This project is a major step toward realizing the goals of the National Quantum Mission on the ground.
- **Global Hub:** To make Amaravati an international hub for quantum technologies (research, development, and innovation).
- **Indigenous Quantum Computer:** To establish India's first **133-qubit (Qubit) quantum computer** by the year 2026.
- **Applications:** Achieving self-reliance in the fields of quantum communication, computing, and sensing.
- **Triple Helix Model:** This project is based on a unique model of collaboration called the **'Tripartite Alliance'**:
  - **Government:** Policy and financial support.
  - **Industry:** Technical and infrastructural assistance from major private companies like **IBM, TCS, and L&T**.
  - **Academia:** Participation of higher education institutions and researchers.

3 Defence Technology

INDIAN DEFENCE

Defence is protecting the integrity, sovereignty, international borders and geo-economic interests of a nation. The Indian Defence system has been organised with the **President as the supreme commander** at the helm and the **Ministry of Defence**, which exercises **administrative control over the armed forces**. Indian Defence has been divided into three services:

- **Indian Army:** Around 1.3-1.4 million active personnel organised under six operational and one training command.
- **Indian Air Force:** over 127000 active personnel organised under five operational, one training and one maintenance command.
- **Indian Navy:** Blue water Navy with strength of 58000 plus active personnel.

Blue Water Navy: Navy who has the capacity to project itself over a much bigger maritime area than its maritime borders.

Brown Water Force: Navy whose operations are restricted close to the shore

Green Water Force: Navy who can project themselves into the littoral waters.

Ministry of Defence

The Ministry of Defence comprises five Departments, viz. **Department of Defence** (DOD), **Department of Defence Production** (DDP), **Department of Defence Research & Development** (DDR&D), **Department of Ex-Servicemen Welfare** and also **Department of Military Affairs**.

Defence Acquisition Council

The Defence Acquisition Council (DAC) is the highest decision-making body within the Indian **Ministry of Defence** for procurement matters. Its primary objective is to ensure timely and efficient acquisition of defense equipment and services to meet the needs of the armed forces.

Key Functions

- **Long-Term Planning:** Approves a 15-year Long Term Integrated Perspective Plan (LTIPP) for defence procurement.
- **Acquisition Proposals:** Assesses and categorises acquisition proposals into 'Buy,' 'Buy & Make,' and 'Make' categories.
- **Single Vendor Clearance:** Addresses issues related to single-vendor procurement.
- **Offset Provisions:** Takes decisions on offset requirements for acquisitions exceeding Rs 2000 crore.
- **Technology Transfer:** Oversees technology transfer in 'Buy & Make' category proposals.
- **Field Trial Evaluation:** Evaluates the performance of defence equipment in field trials.

Composition

- **Chairman:** Defense Minister
- **Members:** Chief of Defense Staff (CDS), Chiefs of Army, Navy, and Air Force

The DAC was formed in 2001, following the Group of Ministers' recommendations on reforming the national security system, in response to the Kargil War.

Defence Research and Development Organisation (DRDO)

Established in **1958** with the objective of **Military research**, achieving **self-reliance** in defence technology and development of **advanced technologies** in diverse areas, including missile systems, aeronautics, electronics etc. The **Scientific Advisor** of the **Defence Ministry** is the **secretary of DDRD (Department of Defence)** and **the chairman of DRDO**.

The motto of DRDO is "Balasya Mulam Vigyanam", meaning "Strength's Origin is in Science." **(RAS 2021)**

- **Important Contributions of DRDO**
  - **Missile Systems:** Agni series for deterrence, Prithvi, Akash, Nag for various applications.
  - **Aerospace Technologies:** LCA Tejas. Tracy Kidder
  - **Radar and EW Systems:** Arudhra, Rohini radars, electronic warfare advancements.
  - **Naval Systems:** Sonar systems, BrahMos supersonic cruise missile.
  - **Armoured Vehicles:** Arjun tank. (RAS 2013)
  - **UAVs and Drones:** Surveillance, combat UAVs, advancements in drone tech.

Besides the above, DRDO has also played an important role in the development of Nuclear Capabilities, Cyber Security, Biomedical Technologies, Strategic Technologies (AI, Quantum Tech) etc.

Application of Drones

1. Spraying pesticides on a crop field
2. Inspecting the craters of active volcanoes
3. Collecting breath samples from spouting whales for DNA analysis.

NTRO (National Technical Research Organisation)

- Technical Intelligence Agency under the National Security Advisor in the Prime Minister's Office, which operates as an autonomous organisation
- Primary objective is the acquisition of technical intelligence involving the interception and analysis of communication signals, imagery intelligence, and cyber intelligence.
- **National Institute of Cryptology Research and Development** functions under it.

Developed by the Defence Research and Development Organisation (RAS 2018/2016)

Amtooth

- **Type:** A polyherbal solution.
- **Purpose:** Formulated to check and treat toothaches caused by the inflammation of dental nerves. It is also effective against hot and cold sensations in the gums.
- **Efficacy & Testing:** Clinically evaluated for efficacy at the District Hospital and Military Hospital in Pithoragarh, Uttaranchal.
- **Action Time:** Relieves pain within 2 to 5 minutes of application.

Lueskin

- **Purpose:** Developed for the treatment of leucoderma, keeping in mind the associated social stigma, limitations of existing therapies, and the etiology (cause) of the disease.
- Forms: Available as an ointment and a liquid oral dose.
- **Key Benefits:** Stops recurrence of the disease, prevents blister formation, and offers better efficacy than existing market products with no side effects.

Eczit

- **Type:** A polyherbal product.
- **Purpose:** Formulated for the treatment of eczema or Atopic Dermatitis.
- **Key Benefits:** Effective against all kinds of eczema, stops recurrence, and demonstrates better efficacy than other products available on the market with no side effects.

Nocdurna

- **Purpose:** Helps control increased thirst and excessive urination, which aids in preventing dehydration.
- **Active Component & Usage:** Contains Desmopressin. It is specifically used by adults who wake up 2 or more times during the night to urinate due to a condition known as nocturnal polyuria.

Chief of Defence Staff

Background and Establishment

- **Recommendations:** The establishment of the CDS was recommended by the Group of Ministers (GoM) in 2001 and further supported by the **Naresh Chandra Committee in 2012.**
- **Creation:** Created in 2019, with General Bipin Rawat serving as the first incumbent.

Roles and Responsibilities

- **Inter-Service Coordination:** Fosters synergy among the Army, Navy, and Air Force.
- **Military Advisor:** Serves as the single-point military advisor to the Defence Minister.
- **DMA Head:** Heads the Department of Military Affairs, overseeing inter-service procurement and decision-making.
- **Directives:** Provides directives to the service chiefs, though without direct command authority.
- **Rank and Authority:** CDS is a four-star General and heads the Department of Military Affairs.
- **Nuclear Command Authority:** Serves as an advisor to the NCA.

Defence Systems used in Operation Sindoor

Defence System	Description	Primary Function
SCALP Cruise Missile	SCALP (Storm Shadow) is a long-range, air-launched cruise missile used for deep strikes.	Precision strikes against high-value, fixed targets, such as fortified positions and critical infrastructure in enemy territory.
HAMMER Precision-Guided Bomb	HAMMER (Highly Agile Modular Munition Extended Range) is a precision-guided bomb with modular capabilities.	Precision strikes against enemy targets, enhancing flexibility with extended range and multiple configurations for different missions.
Loitering Munitions	Known as kamikaze drones, loitering munitions are used for surveillance and target engagement. They remain in the air over enemy territory, waiting for the right moment to strike.	Surveillance and target engagement, executing precision strikes after loitering over enemy territory. They are self-destructive once the target is locked.

MISSILE SYSTEMS

Considering the importance of guided missile weapon systems in modern warfare, a Special Weapon Development Team (SWDT) was formed in 1958, which was expanded into the **Defence Research & Development Laboratory** (DRDL) in June 1961. Projects under the DRDL include:

- Development of an anti-tank missile system and indigenous rockets initially.
- **Project Devil** (initiated: 1972) for the development of a **medium-range Surface-to-Surface Missile**.
- DRDL (1982 onwards) has undertaken the design and development of various types of missile systems under **the Integrated Guided Missiles Development Programme (IGMDP)**.

Integrated Guided Missiles Development Programme (IGDMP) (RAS 2013)

IGMDP (**conceived by Dr. A.P.J. Abdul Kalam**) was started in 1983 to develop **Prithvi**, **Trishul**, **Akash**, **Nag** and **a Technology Demonstrator Agni Missile**.

The technology demonstrator missile of the Agni series (**tested in 1989**) was developed under the IGMDP. Afterwards, the **Agni missile program was detached from the IGMDP**.

Surface-to-Surface Ballistic Missiles

- **Prithvi:** A family of short-range ballistic missiles with variants Prithvi I, II, and III.
- **Dhanush:** A naval variant of Prithvi with a range of 350 km.
- **Agni:** A series of medium and long-range ballistic missiles, including Agni-I, II, III, IV, V, and VI. [Note - Agni missile development moved out of IGMDP after the Agni-II. Agni series is no longer part of IGMDP since 1999.]

Surface-to-Air Missiles

- **Trishul:** A quick-reaction, short-range missile with electronic countermeasures.
- **Akash:** A short-range missile system with built-in ECCM (**Electronic Counter-Counter Measures**) capabilities.
  - **ECCM:** Electronic counter-countermeasures is a part of electronic warfare which includes a variety of practices which attempt to reduce or eliminate the effect of electronic countermeasures on electronic sensors aboard vehicles, ships and aircraft and weapons such as missiles.
- **NAG:** An anti-tank guided missile with fire-and-forget capabilities.
  - **NAG missile carrier (NAMICA)**, a BMP II based system with amphibious capability, has been developed.
  - **HELINA (DHRUVASTRA), an abbreviation for Helicopter Launched NAG, is an air-to-surface missile system** mounted on the **Advanced Light Helicopter** (ALH) with an operational range of 0.5-7 km.

Missile	Range (km)	Payload (kg)	Type
Prithvi I	150	1000	Short-range
Prithvi II	350	500-1000	Medium-range
Prithvi III	350	1000	Medium-range
Dhanush	350	500	Medium-range (naval)
Trishul	9-12	N/A	Surface-to-air
Akash	4.5-25	710	Surface-to-air
NAG	0.5-4	N/A	Anti-tank guided
Agni-I	700-1200	1000	Short-medium range
Agni-II	2000+	1000	Medium-range
Agni-III	3000+	1500	Intermediate-range
Agni-IV	4000	1000	Intermediate-range
Agni-V	5000+	1500	Intercontinental-range
Agni-VI (under development)	9000-12000	3000	Intercontinental-range (MIRV capable)
Agni-P	1000-2000	1000	Medium-range

ASTRA Missile (BVR Air-to-Air Missile) (RAS 2024/2018)

- The ASTRA missile, successfully test-fired from the LCA Tejas on 23 August 2023, is an indigenously developed Beyond Visual Range Air-to-Air Missile (BVR-AAM) designed by DRDO.
- A BVR Air-to-Air Missile is capable of detecting, tracking, and destroying enemy aircraft at distances beyond the pilot's visual range, typically exceeding 20–30 km.

Key Features

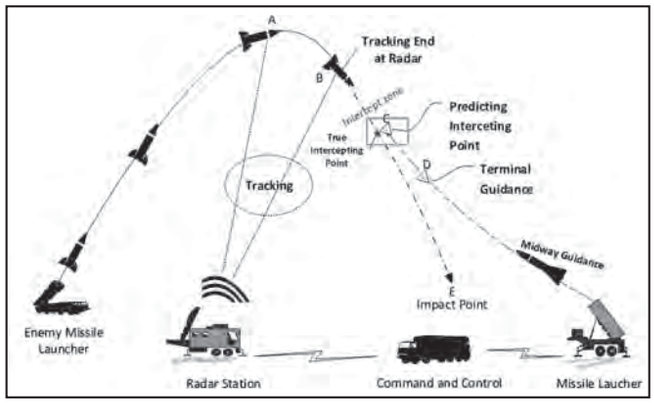
- **Long-Range Engagement:** Capable of striking airborne targets at distances beyond visual range.
- **Advanced Guidance Systems:**
  - Active Radar Homing
  - Semi-Active Radar Homing
  - Infrared (IR) Homing (terminal phase)
- **Mid-Course Updates:** Allows trajectory correction during flight based on target movement.

- **Data-Link Communication:** Enables real-time target information exchange with the launching aircraft.
- **High Accuracy:** Effective against fighter aircraft, UAVs, and other aerial threats.

Ballistic Missile

A ballistic missile follows an arcing trajectory, guided only during specific stages of flight. It uses stored energy to propel itself to a predetermined target, where it delivers one or more warheads. Factors such as gravity, air resistance, and the Earth's rotation influence the missile's path, which is determined by its initial velocity and trajectory.

- **Prahar:** Short-range (150 km), single-stage solid-fuel missile for rapid strikes.
- **Shaurya:** Nuclear-capable, short-range hypersonic ballistic missile (7.5 Mach) with a range of 1,000 km.
- **K Family:** Submarine-Launched Ballistic Missiles (SLBMs) developed by DRDO.
  - **K-4:** Intermediate-range (3500 km) SLBM with a 2.2-ton payload.
  - **K-15 Sagarika:** Short-range (750 km) SLBM with a 1000 kg payload



Ballistic Missile Defense System

Surface-to-Air Missiles:

- **Quick Reaction Surface-to-Air Missile (QRSAM):** Medium-range (5-30 km), single-stage solid-fuel missile for air defense. (RAS 2024)
- **Medium-Range Surface-to-Air Missile (MRSAM):** Long-range (70 km), high-response missile for neutralising aerial threats.

Long-Range Surface-to-Air Missile (LRSAM):

- **Project Kusha:** India's indigenous long-range air defence system with a range of up to 350 km. (expected to deploy in 2028-29)
- **Capabilities:** Detects and destroys stealth fighters, aircraft, drones, cruise missiles, and precision-guided munitions.
- **High Kill Probability:** Offers a single-shot kill probability of at least 80% and 90% for salvo launches.
- **Salvo:** a simultaneous discharge of two or more guns in military action or the release all at one time of a rack of bombs or rockets.

Cruise Missiles

A cruise missile is a guided missile designed to strike terrestrial targets. Unlike ballistic missiles, which follow an arcing trajectory, cruise missiles fly low and slow, hugging the terrain to avoid detection. This allows them to deliver large warheads over long distances with precision.

Mach: Mach is used as a unit of measurement in stating the speed of a moving object in relation to the speed of sound.

Missile	Type	Range (km)	Payload (kg)	Speed	Characteristics
Nirbhay	Subsonic Cruise Missile	750-1000	500	0.7 Mach	Indigenous, low-altitude flight, nuclear capable
Brahmos	Supersonic Cruise Missile	290 (extends upto 400-500 Km)	300	2.8 Mach	India-Russia joint venture, land/sea/air launch, fire-and-forget
Brahmos NG	Supersonic Cruise Missile	290	300	3.5 Mach	Lightweight air-launched version for LCA Tejas
Brahmos II	Hypersonic Cruise Missile	about 1000 km	300	6 Mach	Hypersonic speed, under development
Moskit	Supersonic Anti-Ship Cruise Missile	120	Convention-al/Nuclear	Mach 3 (high altitude), Mach 2.2 (low altitude)	Fastest flying anti-ship missile

Cruise Missile Propulsion

Engine Type	Propulsion Method	Operating Speed	Advantages	Disadvantages
Ramjet	Air-breathing, subsonic combustion	Mach 2+	Simple design, no moving parts	Inefficient at high speeds, launch requirements
Scramjet	Air-breathing, supersonic combustion	Mach 5+	Efficient at high speeds	Complex design, high temperatures
Dual-Mode Ramjet (DMRJ)	Air-breathing, subsonic/ supersonic combustion	Mach 4-8	Efficient across a wide speed range	Complex design
Solid Fuel Ducted Ramjet (SFDR)	Solid fuel, air-breathing	Mach 3-5	Long-range interception, high speed	Solid fuel limitations

Turbojet: The turbojet is an airbreathing jet engine which is typically used in aircraft. It consists of a gas turbine with a propelling nozzle.

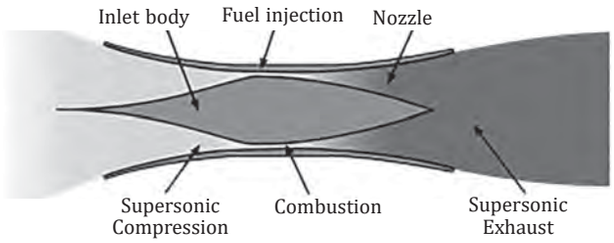


Figure: Scramjet

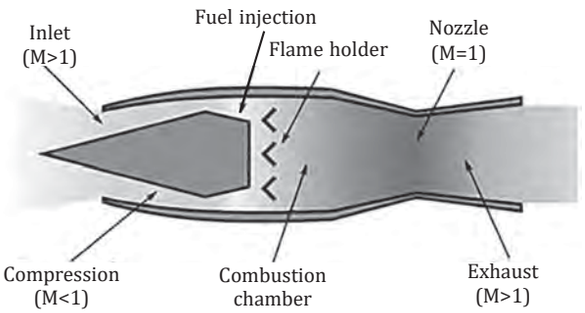


Fig. 3.1: Ramjet

Comparison of Ballistic and Cruise Missiles

Feature	Ballistic Missile	Cruise Missile
Trajectory	Ballistic	Atmospheric, guided
Target Selection	Predetermined	Can be mobile
Target Size	Suitable for large targets	More suitable for small, mobile targets
Guidance	Brief guided flight, mostly gravity-driven	Self-navigating
Altitude	High elevation	Can fly at very low altitudes
Tracking	Simple to follow	Difficult to track due to low altitude

Anti Ballistic Missile System

India's Ballistic Missile Defense (BMD) Program is a multi-layered initiative to protect the nation from ballistic missile threats. The system is designed to intercept missiles in two phases:

Phase 1 focuses on intercepting missiles with a range of up to 2000 km. Key components include:

- **Prithvi Air Defense (PAD)/Pradyumna:** An exoatmospheric interceptor with a range of 300-2000 km and a maximum altitude of 80 km.
- **Advanced Air Defense (AAD)/ Ashwin:** An endo atmospheric interceptor designed to destroy targets in the lower atmosphere.
- **Prithvi Defense Vehicle:** Similar to PAD but with an enhanced flight altitude of 150 km.
- **Prithvi Defense Vehicle Mk-2 /ASAT:** An exoatmospheric interceptor capable of intercepting missiles or satellites in orbit.
- **Swordfish RADAR:** A long-range tracking radar for detecting and tracking ballistic missiles.

Phase 2 is under development and will be capable of intercepting missiles up to 5000 km. Key components include:

- **Air Defense 1 (AD-1):** A long-range interceptor missile designed for both low exoatmospheric and endoatmospheric interception.
- **Air Defense 2 (AD-2):** A future interceptor capable of neutralizing missiles with even higher ranges.

Other Defence System

Foreign Systems

- **NASAMS-II:** A U.S.-developed system designed to counter threats like cruise missiles, aircraft, and drones. It will complement existing Russian (Pechora) and Israeli (Spyder) defence systems.

- **S-400 Triumf:** A Russian long-range system capable of intercepting aircraft, UAVs, cruise missiles, and ballistic missiles. It offers advanced tracking and targeting capabilities.
- **Iron Dome:** An Israeli system designed for short-range missile defence, known for its high interception rate and ability to discriminate between threats.

Indigenous Systems

- **RUDRAM Anti-Radiation Missile:** Developed by DRDO, RUDRAM is an indigenous missile designed to target enemy radars and air defences.
- **Sudarshan Bomb:** A laser-guided bomb developed by DRDO with a range of up to 50 km.
- **RaIDer-X:** An explosive detection device developed by DRDO and IISc Bangalore.

Future Developments

- India's ongoing efforts to develop indigenous offensive strategic warhead delivery system such as the Fractional Orbital Bombardment System (FOBS), demonstrate its commitment to technological self-reliance.
  - **Fractional Orbital Bombardment System (FOBS)** is a warhead delivery system that uses a low Earth orbit to target its destination. It was first developed by the Soviet Union and offers unlimited range.

CL-20, HMX and LLM-105 are High-Energy Materials (HEMs) specifically military explosives used in warheads, missiles, artillery shells, and detonators.

FIGHTER JETS

First Generation

- **MiG-21:** An older model, but still in service; known for its speed and agility. Used primarily for air defense and ground attack missions.

Second Generation

- **MiG-29:** A twin-engine air superiority fighter known for its maneuverability and effectiveness in both air-to-air and air-to-ground roles.

Third Generation

- **Sukhoi Su-30MKI:** A multirole air superiority fighter developed in collaboration with Russia. Known for its advanced avionics, agility, and capability to carry a wide range of weapons.
- **Jaguar:** A ground attack aircraft designed for strike missions.

Fourth Generation

- **Dassault Rafale:** A French multirole fighter jet known for its versatility and advanced technology. Equipped with cutting-edge avionics and weaponry, including nuclear capabilities.
- **HAL Tejas:** An indigenous lightweight, multirole fighter developed by Hindustan Aeronautics Limited. Designed for air-to-air and air-to-ground combat, with advanced features and systems.

Proposed (Next Generation)

Boeing F/A-18 Super Hornet: Considered a multirole fighter with advanced systems.

Eurofighter Typhoon: A European multirole fighter known for its cutting-edge capabilities.

The Dornier-228 is a highly versatile aircraft used for missions such as maritime patrol, surveillance, pollution control, search and rescue, and medical evacuation. The Ilyushin Il-76 {The Ilyushin Il-78 is the Indian Air Force's aerial refueling tanker aircraft used for air-to-air refueling operations.(RAS 2016)} and C-17 Globemaster III are heavy military transport aircraft designed for strategic airlift and large cargo operations. In contrast, aircraft like HAL Tejas, MiG-21, Sukhoi Su-30MKI, and Dassault Rafale are supersonic combat aircraft, built for high-speed air defence and offensive missions.

AIRCRAFT CARRIERS (RAS 2013)

INS Vikramaditya

- **Origin:** Refurbished Russian aircraft carrier Admiral Gorshkov.
- **Commissioned:** Indian Navy, Severodvinsk, Russia.
- **Size:** Largest ship in the Indian Navy, measuring over 285m long, 60m wide, and 60m high.
- **Personnel:** Houses over 1,600 personnel, earning it the nickname "Floating City."
- **Range:** Operational range of over 13,000 km.
- **Aircraft Capacity:** Can carry over 30 aircraft, including MiG-29K/Sea Harrier, Kamov 31, Kamov 28, Sea King, ALH-Dhruv, and Chetak helicopters.
- **Landing Systems:** Features LUNA Landing system for MiGs and DAPS Landing system for Sea Harriers.

INS Vikrant

- **Speed:** Maximum speed of 28 knots.
- **Aircraft Capacity:** Can operate 30 aircrafts, including MiG-29K fighter jets, Kamov-31, MH-60R multi-role helicopters, ALH, and LCA (Navy).
- **Aircraft Operations:** Employs STOBAR (Short Take-Off but Arrested Landing) mode and is equipped with a ski-jump and arrester wires.
- **Indigenous Content:** Boasts an overall indigenous content of 76%.

IMPORTANT VESSELS OF THE INDIAN NAVY

Indigenous Vessels

1. **INS Astradharini (2015)**
   - A torpedo launch and recovery vessel, 95% indigenously built.

- Designed by NSTL, M/s Shoft Shipyard, and IIT Kharagpur.
- Has a length of 50 meters and can operate in high seas with a maximum speed of 15 knots.
- Used for technical trials of underwater weapons and systems developed by NSTL.
- Replaced INS Astravahini.

2. INS Kavaratti (2015)

- A Kamorta class anti-submarine warfare (ASW) stealth corvette, 90% indigenous.
- Designed by DND(Directorate of Naval Design) and built by GRSE, Kolkata(Govt. owned undertaking of Ministry of Defence).
- Capable of detecting and prosecuting submarines.
- Uses carbon composites in construction.
- One of four ships commissioned under Project 28, along with INS Kamorta, INS Kadmatt, and INS Kiltan.

3. Project 17 A (Ongoing)

- Guided missile frigates, 75% indigenous. Frigates designed under it aims to operate in a 'Blue Water' environment, meaning they can handle both conventional and non-conventional threats
- Designed by the Indian Navy's Warship Design Bureau.
- Being built by M/s MDSL ((Mazagon Dock Shipbuilders Ltd))and M/s GRSE (Garden Reach Shipbuilders and Engineers).
- Follow-ons of the Shivalik class frigates with improved features.
- The seven ships under Project 17A, are INS Nilgiri, INS Udaygiri, INS Himgiri, INS Taragiri, INS Mahendragiri, INS Dunagiri, and INS Vindhyagiri.

4. Project 15 B (Ongoing)

- Advanced variants of the Kolkata class guided missile destroyers, 75% indigenous.
- Designed by the Warship Design Bureau and being built by M/s MDSL.
- Includes four ships: INS Visakhapatnam, INS Mormugao, INS Imphal, and INS Surat.

Non-Indigenous Vessels

INSV Tarini (2017)

- A 55-foot sailing vessel used for the Navika Sagar Parikrama expedition.
- Not indigenous, but a significant achievement for the Indian Navy.
- Successfully circumnavigated the globe with an all-woman crew.

SUBMARINES

India currently possesses a fleet of 15 conventional diesel-electric submarines (SSKs) and two nuclear ballistic submarine (SSBN). Submarines are critical assets for any modern navy, providing capabilities for stealth, deterrence, and combat in underwater environments.

Types of Submarines

- **Diesel-Electric Submarines (SSKs):** Use electric motors charged by diesel engines for propulsion. Require frequent resurfacing for air and fuel, making them easier to detect.
  - **Shishumar Class:** Four submarines bought and built in India in collaboration with Germany.
  - **Kilo Class (Sindhughosh Class):** Eight submarines bought from Russia between 1984 and 2000.
  - **Kalvari Class (Scorpene):** Three submarines built in India in partnership with France.
- **Nuclear-Powered Attack Submarine (SSN):** Can stay underwater indefinitely, limited only by food supplies. Equipped with torpedoes, anti-ship cruise missiles, and land-attack cruise missiles.
  - **INS Chakra:** INS Chakra is a nuclear-powered attack submarine (SSN) of the Indian Navy, leased from Russia.(RAS 2016/2013)
  - **INS Chakra 2:** Leased from Russia until 2022.
- **Nuclear-Powered Ballistic Missile Submarine (SSBN):** A slow-moving platform for launching nuclear weapons.
  - **Arihant:** India's first SSBN, with three more under construction.

INS Arihant (RAS 2013)

INS Arihant is a crucial component of India's nuclear triad, providing the capability to launch nuclear weapons from submarines. This strategic advantage is particularly significant given India's "no first use" policy.

- As a nuclear-powered ballistic missile submarine (SSBN), INS Arihant was commissioned in 2016. It is currently armed with K-15 SLBMs with a range of 750 kilometers.
- **INS Arighat:** India's second nuclear powered submarine commisioned in 2024, bolstering India's strategic deterrence.
- **Nuclear Triad** means the capability of delivering nuclear weapons by aircraft, land based ballistic missiles and submarine launched missiles.

Project 75

Entails indigenous construction of **SSK submarines** of **Scorpene design** by **M/s MDSL**. The project includes the commissioning of six vessels, including **INS Kalvari**, **INS Khanderi**, **INS Karanj**, **INS Vela**, **INS Vagir**, and **INS Vagsheer**.

Project 75 (I)

It is a follow-up and improvement over **Project 75. The initiative envisages new SSK submarines** with **fuel cells** and **Air-Independent Propulsion System (AIP)** for the Indian Navy**.**

AESA (Active Electronically Scanned Array) Radar

AESA is an advanced radar system that uses solid-state active phased-array technology.

Capabilities:

- Tracks multiple targets simultaneously.
- Provides superior detection and resistance to electronic jamming.
- Features a wide-band RF front end.
- Can be integrated into various fighter aircraft platforms. (RAS 2024)

UNMANNED AERIAL VEHICLES (UAV)/DRONE AND ROBOTS

UAV/Drone is a military aircraft/land-water based vehicle that is guided autonomously, by remote control, or both and that carries sensors, target designators, offensive ordnance, or electronic transmitters designed to interfere with or destroy enemy targets.

Unmanned Aerial Vehicles (UAVs) differ widely in design and capability. Vertical Take-Off and Landing (VTOL) UAVs, such as multi-rotor drones and some hybrid tilt-rotor models, can take off, land, and hover vertically, making them ideal for precision tasks like photography, surveillance, delivery, and rescue. Fixed-wing UAVs, on the other hand, cannot hover or land vertically; they require runways or launch-and-recovery systems but excel in energy efficiency, speed, and long-endurance missions such as long-range surveillance. Hybrid UAVs combine features of both types, depending on design.

UAVs also use varied power sources—batteries for small drones, gasoline or hybrid engines for long-endurance military UAVs, and even solar or hydrogen systems for high-altitude, long-duration missions—chosen according to mission range, payload, and endurance requirements.

Name	Indigenous/Imported From	Utility
NETRA	Indigenous (DRDO)	Airborne Early Warning and Control System (AEW&C/AWAC) for surveillance, target tracking, and command and control
Lakshya 2	Indigenous (DRDO)	Advanced pilotless target aircraft (PTA) for training air defense systems, simulating enemy aircraft, and evaluating weapon systems
Nishant	Indigenous (DRDO)	Battlefield surveillance, reconnaissance, target tracking, localization, intelligence gathering, and electronic warfare support
Panchi	Indigenous (DRDO)	Tactical UAV with conventional take-off/landing for reconnaissance, surveillance, target acquisition, and communication relay
Daksh	Indigenous (DRDO)	IED identification and handling, nuclear/chemical contamination monitoring, explosive ordnance disposal (EOD), and search and rescue operations
Daksh Mini	Indigenous (DRDO)	Confined space ROV for inspecting hazardous areas, extracting suspicious objects, and supporting search and rescue operations
UXOR	Indigenous (DRDO)	Unexploded ordnance (UXO) handling and detection, neutralizing bombs and missiles up to 1000 kg
UAV-NETRA	Indigenous (DRDO)	Mini UAV for surveillance, reconnaissance, intelligence gathering, and border monitoring
Rustom 2	Indigenous (DRDO)	Long-endurance MALE UAV for intelligence, surveillance, reconnaissance (ISR), electronic warfare, communication relay, and precision strike
Heron	Imported (Israel)	Medium-altitude long-endurance (MALE) UAV for ISR, border surveillance, target acquisition, and communication relay
FireFly	Imported (Israel)	Loitering munition for precision strikes against ground targets

Harpy/Harop	Imported (Israel)	Loitering munitions for electronic warfare and precision strikes
Predator	Imported (United States)	Medium-altitude long-endurance (MALE) UAV for ISR, strike missions, and combat search and rescue
Sea Guardian	Imported (United States)	Maritime surveillance UAV for maritime domain awareness and anti-submarine warfare

System	Origin	Role/Operational Use
Bhargavastra Micro Missiles	Indigenous (India)	Micro-missile system developed to neutralize swarm drone threats.
Swarm Drones	Indigenous (India)	Smart War-Fighting Array of Reconfigured Modules (SWARM), consisting of multiple drones working in coordination

Year of Defence Reforms' – 2025

- **Focus Areas:** Jointness & Integration, Strengthen inter-service integration and establish Integrated Theatre Commands.
- **Cooperation & Training:** Foster inter-service cooperation and joint training for unified operational capabilities.
- **Joint Logistic Nodes (JLNs):** Since 2021, three Joint Logistic Nodes (JLNs) have been established in Mumbai, Guwahati, and Port Blair to integrate logistics across the Indian Armed Forces. These JLNs provide logistical support for ammunition, rations, fuel, stores, transport, aviation clothing, spares, and engineering support, enhancing operational synergy between the services.
- **Inter-Services Organisations (Command, Control & Discipline) Act, 2023:** It promotes jointness in the Indian Armed Forces by empowering commanders of tri-service formations with authority over personnel from all three Services. This unifies the disciplinary chain, speeds up decision-making, and fosters operational and cultural integration.
- **Integrated Theatre Commands (ITCs):** To optimize operational preparedness by unifying the Army, Navy, and Air Force capabilities based on geography and function.

INTERNATIONAL ORGANISATIONS AND CONVENTIONS

Biological Weapons Convention (BWC)

It effectively prohibits the development, production, acquisition, transfer, stockpiling and use of **biological** and **toxin weapons**. It was the **first multilateral disarmament treaty** banning an entire category of **weapons of mass destruction** (**WMD**). **India has signed and ratified the convention.**

Organisation for the Prohibition of Chemical Weapons (OPCW)

It is the i**mplementing body for the Chemical Weapons Convention** based in Hague, Netherlands, which oversees the global endeavour to permanently and verifiably eliminate chemical weapons. **India is a signatory and party to the Chemical Weapons Convention.**

Australia Group

It is an informal forum of countries which seeks to ensure that **exports do not contribute to the development of chemical or biological weapons.** All states participating in the Australia Group are parties to the **Chemical Weapons Convention** (**CWC**) and the **Biological Weapons Convention** (**BWC**) and **do not undertake any legally binding obligations. India** was **admitted into the group in 2018**.

Wassenaar Arrangement

The Wassenaar Arrangement is the first multilateral body focused on **export controls for conventional arms and dual-use goods and technologies**, and it comprises 42 states (**including India**). **It is consensus-based, with decisions taken on a politically binding basis**.

Missile Technology Control Regime

The Missile Technology Control Regime (MTCR) is an informal political understanding among states that **seeks to limit the proliferation of missiles and missile technology.** It places particular focus on missiles capable of delivering a **payload of at least 500 kg** to a distance of **at least 300 km**-so called '**Category I**' or '**MTCR-class**' missiles. Currently, 35 countries are members of the MTCR, **including India** (**2016**).

Nuclear Suppliers Group (NSG)

The NSG is a group of forty-eight nuclear supplier countries that **seeks to ensure that nuclear trade for peaceful purposes does not contribute to the proliferation of nuclear weapons or other nuclear explosive devices**. **India is not a member of the NSG**, the main reason being its refusal to sign the **Nuclear Non-Proliferation Treaty.**

Comprehensive Test Ban Treaty

It **bans all nuclear explosions**, whether for military or peaceful purposes. The 1996 treaty has so far been signed by 187 states and ratified by 178 states, **yet not in force**. The treaty **awaits signature and ratification** from **India**, **Pakistan**, and **North Korea** and, in addition, requires the **United States**, **China**, **Israel**, **Iran** and **Egypt** (which have already signed) to formally ratify it.

Treaty on the Non-Proliferation of Nuclear Weapons (NPT)

It is a landmark international treaty whose objective is to **prevent the spread of nuclear weapons and weapons technology**, to **promote cooperation in the peaceful uses of nuclear energy** and to **further the goal of achieving nuclear disarmament and general and complete disarmament**. **India** has **not signed the NPT**.

The Treaty on the Prohibition of Nuclear Weapons (TPNW)

Opened for signature in 2017, **it prohibits States Parties from developing, testing, producing, manufacturing, acquiring, possessing, or stockpiling nuclear weapons or other nuclear explosive devices**. The treaty entered into force on 22 January 2021, and **India has neither signed nor ratified it**.

RECENT DEVELOPMENTS IN DEFENCE TECHNOLOGY

Stealth Warship 'Taragiri'

- In order to further strengthen the maritime sovereignty of the Indian Navy, the indigenous state-of-the-art stealth frigate **'Taragiri' (F41)** was commissioned into the Indian Navy at Visakhapatnam on **3 April, 2026**.
- It was handed over to the Navy on **28 November, 2025**.
- This is the **fourth** warship of the **Nilgiri-class (Project 17A)** and the **third** warship built by **Mazagon Dock Shipbuilders Limited (MDL)**.
- **Features of Taragiri:**
  - **State-of-the-Art Capability:** Weighing approximately **6,670 tonnes**, this ship is capable of achieving speeds of more than **28 nautical miles**. Its special stealth design prevents it from being detected by enemy radar.
  - **Indigenous Strength:** More than **75% indigenous content** has been used in this warship, the construction of which was supported by more than **200 MSMEs** across the country.
  - **Lethal Weaponry:** It is equipped with **BrahMos supersonic missiles**, **Medium Range Surface to Air Missiles (MRSAM)**, and an advanced **Anti-Submarine Warfare (ASW) suite**.
- **Propulsion:** It is fitted with a **'Combined Diesel or Gas' (CODOG)** plant, which provides high power to it for long-range missions.
- **Historical Context:** This ship is a modern avatar of the old **'INS Taragiri' (Leander-class frigate)**, which served in the Indian Navy from the year **1980 to 2013**.

INS Anjadip

- On **27 February, 2026**, the state-of-the-art warship **'INS Anjadip'** was commissioned at a formal ceremony organized at the **Chennai Port**. Due to its unerring striking capability and expertise in detecting underwater threats, it has been given the nickname **'Dolphin Hunter'**.
- **Project:** This is the **fourth warship** of the **'Anti-Submarine Warfare Shallow Water Craft' (ASW-SWC)** project.
- **Size and Weight:** Its length is **77 meters** and its weight is approximately **1400 tonnes**.
- **Construction:** It has been constructed by **Garden Reach Shipbuilders & Engineers (GRSE)** at **Kattupalli in Chennai** in collaboration with **L&T**.
- **Replacement:** This indigenous warship will replace the Navy's aging ships of the **'Abhay class'**.
- **Naming and Historical Legacy:**
  - **Source of the Name:** The name 'Anjadip' is derived from a **historical island** located off the coast of Karwar (Karnataka).
  - **Rebirth:** This vessel will carry forward the legacy of the former **I.N.S. Anjadip (Petya class corvette)**, which was decommissioned in the **year 2003**.
- **Specialization and Combat Capability:**
  - **Special Design:** It has been specially designed for **anti-submarine warfare** in shallow coastal waters.
  - **State-of-the-Art Equipment:** The ship is equipped with a modern ASW suite and an **'Integrated Advanced Combat Management System'**, which is capable of tracking and destroying underwater threats.

VSHORADS Missile System (RAS 2024)

- **The Defence Research and Development Organisation (DRDO)** conducted three consecutive successful flight tests of the indigenously developed **'Very Short Range Air Defence System' (VSHORADS)** in **February 2026**. These tests were carried out from the **Integrated Test Range (ITR) located at Chandipur** off the coast of Odisha.
- The primary objective of these tests was to verify the **striking capability of the missile system**.
- **Accuracy:** Identifying and destroying high-speed aerial threats flying at different speeds, distances, and altitudes.
- **Capability:** Testing the reliability and stability of the system under various warfare conditions.
- **Technical Characteristics of VSHORADS:**
  - **Type:** It is a **man-portable (man-driven)** air defence system that can be easily transported from one place to another.

- **Striking Capability:** It is capable of targeting and piercing objectives up to a distance of **8 kilometers**.
- **Altitude:** It can destroy threats flying up to an altitude of **4.5 kilometers** from the ground.
- **Targeted Threats:** This system is specifically designed to neutralize drones, helicopters, and low-altitude flying aircraft.

- **Indigenous Manufacturing and Development:**
  - **Main Design:** It has been designed and developed by the **Research Centre Imarat (RCI) located in Hyderabad**.
  - **Collaboration:** Other DRDO laboratories and development-cum-production partners played a significant role in this.
  - **Self-Reliance:** It is completely based on indigenous technology, which promotes India's self-reliance in defence.

Launch of First Indigenous Cadet Training Ship 'Krishna'

- **Launch:** The Indian Navy successfully launched its first indigenous Cadet Training Ship (CTS) 'Krishna' (Yard 18003) on 16 February, 2026, at Kattupalli, Chennai (L&T Shipyard).
- **Development:** This is the first vessel in a series of three ships being built by L&T, which will be handed over to the Navy by the end of 2026.
- **Inauguration:** It was unveiled by Smt. Anupama Chauhan (wife of CDS General Anil Chauhan).
- **Objective:** To provide practical naval training at sea to Indian cadets (including female cadets) and cadets from friendly foreign nations.
- **Capacity:** This state-of-the-art vessel can accommodate 20 officers, 150 sailors, and 200 cadets simultaneously.

'Samudra Pratap': The Country's First Indigenous Pollution Control Vessel (PCV)

- **Commissioning:** Defence Minister Rajnath Singh commissioned this first indigenous and largest vessel of the Indian Coast Guard (ICG) in Goa on 5 January, 2026.
- **Construction:** Built by Goa Shipyard Limited (GSL) with more than 60% indigenous content.
- **Record:** This is the largest ship in the ICG fleet to date (length 114.5 meters, displacement 4,170 tonnes).
- **Technology:** It is equipped with modern equipment (skimmers, booms) to contain oil spills at sea.
- **Headquarters:** Kochi (Western Command).
- **Women Empowerment (Nari Shakti):** For the first time, two women officers have been deployed on this ship.
- **Objective:** Marine pollution control, Search and Rescue (SAR), and surveillance of the Exclusive Economic Zone (EEZ).

Stratospheric Airship Platform (SAP)

- **Testing:** DRDO conducted its first successful test.
- **Type:** It is an unmanned airship.
- **Development:** Aerial Delivery Research and Development Establishment (ADRDE), Agra.
- **Operation:** It operates in the stratosphere at an altitude of 17–22 km.
- **Classification:** It functions as a High Altitude Pseudo Satellite (HAPS).
- **Applications:** It is capable of staying in the air for long durations, making it useful for continuous surveillance. It is also helpful in disaster management and espionage operations.

Kaal Bhairav

- **India's first indigenous combat AI drone.**
- This is a **Medium Altitude Long Endurance (MALE) drone.**
- **Manufacturing:** Flying Wedge Defence and Aerospace (FWDA), Bengaluru.
- It is capable of **continuous flight for up to 30 hours** and covering an **operational range of 3000 km.**

Anjadip

- **Date of Delivery:** 22 December 2025, Chennai.
- **Introduction and Structure:** This is an **Indian Naval warship** with a length of approximately **77 meters.** It is powered by a **waterjet propulsion system**, making it among the **most advanced and fastest vessels** in its class.
- **Combat Capabilities:** This vessel is equipped with light torpedoes, indigenous anti-submarine rockets, and shallow water sonar, which specifically enables it for **anti-submarine operations.**
- **Significance of the Name:** The name 'Anjadip' is derived from **Anjadip Island in Karnataka.** This vessel is a modern rebirth carrying forward the legacy of the predecessor **INS Anjadip**, which was decommissioned in **2003.**
- **Indigenization:** More than **80% indigenous content** has been used in this warship, and it is equipped with an **indigenous 30 mm naval surface gun**, marking an important step toward a self-reliant India (Atmanirbhar Bharat).

Dharashakti

- This is a **land-based electronic warfare and jamming system.**
- **Development:** Developed by **DRDO.**
- It is capable of **jamming the radar and communication systems** of the enemy.
- **Deployment:** Deployed on the **India-Pakistan border (Jodhpur)** and the **India-China border.**

4 Space Technology

ORIGIN OF UNIVERSE: BIG BANG THEORY

It is believed that the universe was born about 13.8 billion years ago in an event called the Big Bang. It is the most prevailing cosmological model for the birth of the universe.

Big Bang Theory

- It states that at some moment, all of space was contained in a (Known as singularity) of very high-density and high-temperature state from which the universe has been expanding in all directions ever since.
- After the initial expansion, the universe cooled sufficiently to allow the formation of subatomic particles and, later simple atoms.
- The majority of atoms produced by the Big Bang were hydrogen and helium along with trace amounts of lithium and beryllium.
- Giant clouds of these primordial elements (hydrogen and helium) later coalesced through gravity to form stars and galaxies.

Dark Energy and Dark Matter

Component of Universe	Percentage (%)
Dark Energy	68%
Dark Matter	27%
Ordinary Matter	5%
Total	100%

- **Dark Energy:** A mysterious force driving the accelerated expansion of the universe.
- **Dark Matter:** Non-luminous matter that does not emit or interact with electromagnetic radiation, detectable through its gravitational effects.
- **Ordinary Matter:** Includes stars, planets, gas, dust, and all known forms of visible matter

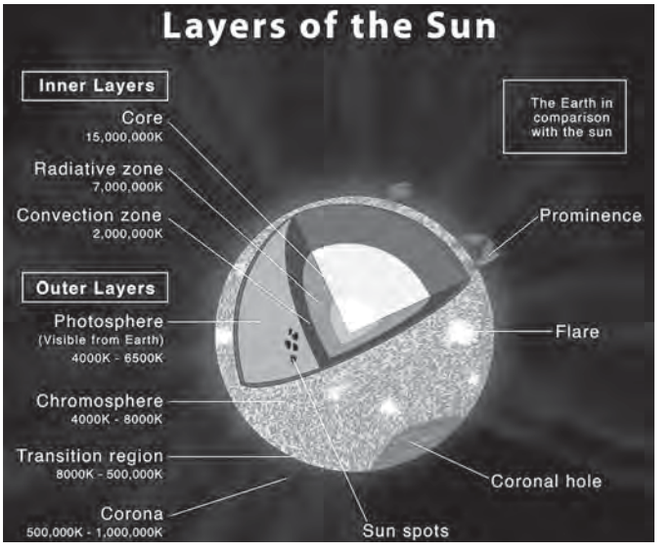
OBSERVING SPACE THROUGH TELESCOPES

Name of Telescope	Description
Hubble Space Telescope	❖ The first major optical telescope launched into space in 1990. ❖ Hubble observes **visible, ultraviolet, and infrared wavelengths** and has provided insights into the universe's size, galaxy and black hole evolution, star lifecycles, and dark energy.
James Webb Space Telescope	❖ Launched in 2021, JWST is NASA'S **primary infrared observatory** designed to study the early universe, galaxy formation, star and planetary system evolution, and the atmospheres of exoplanets. ❖ NASA, the European Space Agency (ESA), and the Canadian Space Agency (CSA) are working together on this project.
Event Horizon Telescope (EHT)	❖ A collaboration of eight radio telescopes used to observe black holes and other astronomical objects. ❖ Captured the first-ever image of a black hole in 2019.
ARIES Telescope	❖ A collaboration between India, Russia, and Belgium, this telescope is located at 2,500 meters in Devasthal, India. ❖ It uses advanced technology for remote control and studies astronomical debris, magnetic fields, planets, and stars.
AstroSat (India)	❖ Launched in 2015, AstroSat is India's first dedicated astronomy satellite. ❖ Unlike **Hubble (visible light) or Chandra (X-ray),** AstroSat observes across the electromagnetic spectrum, studying high-energy processes in binary star systems, neutron stars, and star-forming regions.

Thirty Meter Telescope	❖ An under-construction project at Mauna Kea in Hawaii, involving **India, the US, Canada, China,** and **Japan,** aiming to be one of the world's largest optical telescopes with a 30-meter mirror. ❖ It will provide significantly 12 times sharper images than Hubble and advance research in astrophysics.
SARAS Telescope (India)	❖ A radio telescope used to detect faint radio signals from the early universe, providing insights into the formation of the first stars and galaxies.

SUN CYCLE, SOLAR ECLIPSE AND GEOTAIL

The solar cycle refers to the periodic variation in the Sun's activity, including the number of sunspots, solar flares, and the solar wind. It lasts approximately 11 years on average



Changes in the Sun's magnetic field impact its surface activity. **Sunspots**, cooler regions with strong magnetic fields, are a key indicator of this activity. The solar cycle progresses through distinct phases:

- **Solar Minimum:** The cycle begins with minimal sunspot activity.
- **Solar Maximum:** Sunspot activity reaches its peak.
- **Solar Decline:** Sunspot activity decreases, eventually returning to the solar minimum.

Solar activity during the solar maximum can have effects like:

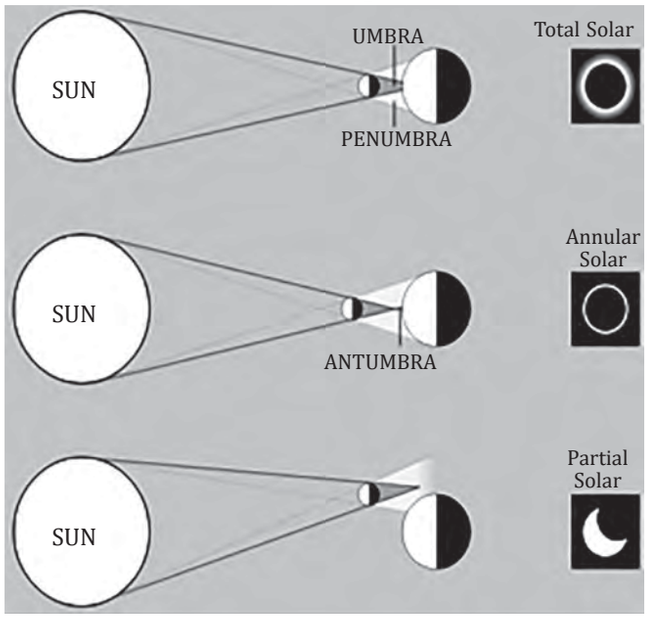
- **Auroras:** Eruptions can cause beautiful auroras, also known as the northern and southern lights.
- **Disruptions:** Strong solar flares can disrupt radio communications and even damage power grids on Earth. Orbits of the satellites could be disturbed. Shortwave radio communication of the aircraft flying over polar regions could be interrupted.

Solar Eclipse

When the moon passes between the sun and the earth, a solar eclipse occurs. The moon stops the sun's light from reaching the earth when this happens. The planet is then bathed in the moon's shadow.

- **There are three Types of Solar Eclipses**: annular solar eclipse, total solar eclipses, partial solar eclipses.

Solar Eclipses



- **Total Solar Eclipse:** Occurs when the Moon completely blocks the Sun, creating a temporary night-like darkness. Only the Sun's corona is visible during totality.
- **Annular Solar Eclipse:** Occurs when the Moon is at or near its farthest point from Earth, appearing smaller than the Sun. This results in a ring of sunlight around the Moon's silhouette.
- **Partial Solar Eclipse:** Occurs when the Sun, Moon, and Earth are not perfectly aligned, causing only part of the Sun to be obscured. People outside the area covered by the Moon's inner shadow will see a partial eclipse.

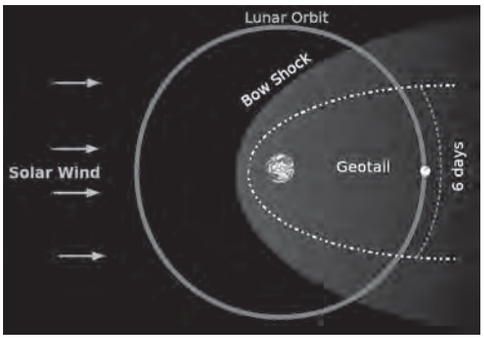
Geotail

The geotail is a region in space formed by the interaction between the Earth's magnetic field and the solar wind, a continuous stream of charged particles emitted by the Sun.

- The Earth's magnetic field acts as a barrier, deflecting the solar wind plasma.
- This interaction creates a magnetic envelope around Earth, compressed on the Sun-facing side and

extended into a long tail i.e. geotail on the opposite side extending beyond the moon's orbit.

- Approximately, once every 29 days, Moon traverses the geotail for about 6 days centered around full moon.



GRAVITY

Gravity is the force by which a planet or other body draws objects toward its center. The force of gravity keeps all of the planets in orbit around the sun.

- Objects with more mass have more gravity. Gravity also gets weaker with distance. So, the closer objects are to each other, the stronger their gravitational pull is.
- It is the weakest of the four fundamental forces but acts over infinite distance and is always attractive.

Variation of Gravity on Earth

Factor	Effect on Gravity
Latitude (Equator vs Poles)	Gravity is weaker at the **Equator** and stronger at the **Poles**.
Altitude (Height above sea level)	Gravity decreases as you move **higher above sea level.**
Local Geological Features	Gravity is stronger in **denser regions** (mountains, minerals) and weaker in **less dense regions** (oceans).
Earth's Rotation	Gravity is weaker at the **Equator** due to **centrifugal force**.

- **GRACE Mission:** NASA uses two spacecraft to measure these variations in Earth's gravity. These spacecraft are part of the Gravity Recovery and Climate Experiment (GRACE) mission.

Einstein's Theory of General Relativity

General relativity, formulated by Albert Einstein in 1915, is a revolutionary theory that fundamentally changed our understanding of gravity and the universe.

- Unlike Newton's theory of gravity, which describes it as a force acting between objects, Einstein's theory proposes that gravity is a curvature of spacetime caused by the presence of mass and energy.
- **Key Principles:**
  - **Equivalence Principle:** The effects of gravity and acceleration are indistinguishable.
  - **Curvature of Spacetime:** Massive objects warp the fabric of spacetime, influencing the motion of other objects.
  - **Gravitational Waves:** Disturbances in spacetime caused by accelerating massive objects, predicted by general relativity and detected in 2015.

Implications

- **Black Holes:** General relativity predicts the existence of black holes, regions of spacetime where gravity is so strong that nothing, not even light, can escape.
- **Gravitational Lensing:** The bending of light by massive objects, as predicted by general relativity, has been observed through gravitational lensing.
- **Cosmology:** General relativity provides the foundation for our understanding of the universe on a large scale, including the expansion of the universe and the formation of galaxies.

Applications

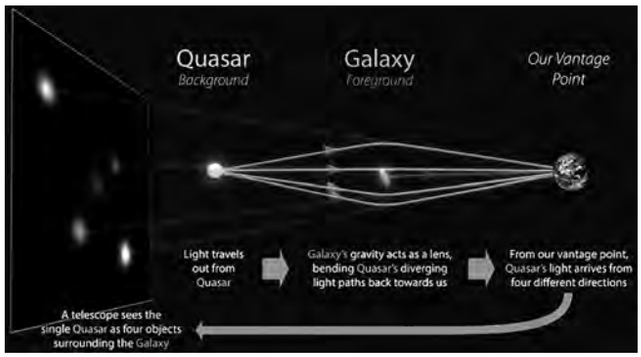
- **GPS Systems:** The accuracy of GPS systems relies on correcting for the effects of general relativity, as the clocks on GPS satellites experience time dilation due to their relative motion and gravitational potential.
- **Astronomy:** General relativity is essential for understanding the behavior of astronomical objects, such as binary stars, neutron stars, and black holes

Gravitational Waves

- Gravitational waves were first proposed by Albert Einstein, 100 years ago as part of the Theory of Relativity.
- In 2016, scientists at Laser Interferometer Gravitational- wave Observatory (LIGO) first detected the gravitational waves.
- The **evolved Laser Interferometer Space Antenna (eLISA)** is a mission aiming at exploring the Gravitational Universe from space for the first time. The experiment will employ a **trio of spacecraft flying in formation in the shape of an equilateral triangle** that has sides one million kilometers long, with lasers shining between the craft.
- GWs are ripples in space-time that move at the speed of light and are created by some of the Universe's most furious and intense processes.
- They hold information about their cataclysmic origins, as well as crucial insights regarding gravity's nature.
- They form when
  - Things move at extremely high speeds,
  - When a star explodes asymmetrically (known as a supernova),
  - When two large stars orbit one other, and
  - When two black holes orbit each other and join.

Gravitational Lensing

Gravitational lensing occurs when a massive celestial body, like a galaxy cluster, bends the path of light passing near it.


Quasar
Background
Galaxy
Foreground
Our Vantage Point
Light travels out from Quasar
Galaxy's gravity acts as a lens, bending Quasar's diverging light paths back towards us
From our vantage point, Quasar's light arrives from four different directions
A telescope sees the single Quasar as four objects surrounding the Galaxy

- This phenomenon, predicted by Einstein's theory of relativity, acts as a cosmic lens, magnifying distant objects that would otherwise be too faint to observe.
- The curvature of spacetime caused by the massive object distorts the light's path, creating distorted images such as rings or halos around the lens.

LIGO- India – InDIGO

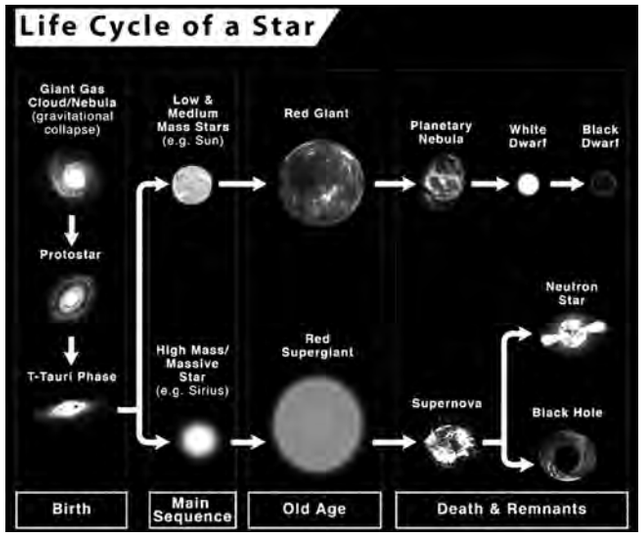
- LIGO-India project is an Indian Initiative in Gravitational
- wave observations (InDIGO), expected to be completed by 2025.
- It aims to move one advanced LIGO detector from Hanford to Maharashtra (Hingoli district), India.
- The project is piloted by the Dept. of Atomic Energy (DAE) and Dept. of Science and Tech (DST).
- **Microgravity**
  - Microgravity research refers to scientific studies conducted in environments where the force of gravity is extremely low, causing objects and people to appear weightless. In such conditions, often found in space or simulated on Earth, researchers can observe how physical, chemical, and biological systems behave differently than they do under normal gravity.
  - -Axiom-4 is a private mission to the ISS that will conduct around 60 scientific studies, including several led by ISRO, with a strong focus on microgravity research across various disciplines such as biology, medicine, and materials science. ISRO and ESA are collaborating on microgravity research experiments specifically for Axiom-4.
  - -SpaDeX is an ISRO technology demonstrator for in-space docking. The mission uses the PSLV's fourth stage (POEM-4) to carry 24 payloads from academia and startups, which will utilize the microgravity environment in orbit for scientific experiments. The mission explicitly provides opportunities for in-orbit microgravity experiments for extended durations.
  - Gaganyaan is India's first human spaceflight mission, led by ISRO. Scheduled to send Indian astronauts into low Earth orbit, it aims to demonstrate indigenous capability in crewed space missions. Gaganyaan will also facilitate scientific research in microgravity, marking a significant milestone in India's space exploration journey.

STARS AND PLANET: LIFE CYCLE OF A STAR

- **Stars** are celestial bodies primarily composed of hydrogen and helium. Through nuclear fusion, they generate light and heat. These luminous spheres of plasma are the fundamental building blocks of galaxies.

Life Cycle of Stars

The stellar evolution infers the process and life cycle of the star from its formation to decay and ultimately death of a star.



Stellar Nebula: The journey of a star begins in a stellar nebula, a vast cloud of gas and dust primarily composed of hydrogen and helium.

Protostar Formation: As the density and temperature within the nebula rise, nuclear fusion reactions ignite at its core, marking the birth of a protostar.

- This dense, hot core continues to gather surrounding gas and dust, eventually evolving into a fully developed star.

T-Tauri Star: Before reaching its stable main sequence stage, a young star passes through the T-Tauri phase. T Tauri stars are characterized by irregular brightness variations and strong stellar winds.

- This transitional phase bridges the gap between protostars and mature stars.

Main Sequence Stars

Main sequence stars are stars that are in the primary phase of their lifecycle, where they spend most of their time fusing hydrogen into helium in their cores. This phase accounts for about 90% of a star's life.

The majority of a star's life is spent in a stable phase on the main sequence. Our Sun is currently a main sequence star.

- **Hydrostatic Equilibrium:** During the main sequence, a star's core is in hydrostatic equilibrium. This means that the outward thermal pressure from nuclear fusion reactions balances the inward pull of gravity, maintaining the star's stability.
- **Nuclear Fusion:** The energy that supports a main sequence star against gravitational collapse comes from nuclear fusion in its core. Hydrogen atoms combine to form helium, releasing a tremendous amount of energy in the process.
- **End of the Main Sequence:** Once hydrogen fusion in the core ceases, the star loses its stability and evolves off the main sequence. The path it takes depends on its mass.
- **Lifespan:** The lifespan of a main sequence star is directly related to its mass. More massive stars burn through their fuel at a faster rate, resulting in shorter lifespans. Conversely, low-mass stars like red dwarfs can shine for tens of billions of years.
- **Red Dwarfs:** Red dwarfs are the smallest and least luminous main sequence stars, typically less than 10% of the Sun's mass. They emit minimal energy and have surface temperatures between 3000-4000K. Despite their small size, red dwarfs are abundant and have extremely long lifespans.

Death of Star

When a **star exhausts the hydrogen** in its core, it undergoes changes leading to its eventual fate.

Red Giants and Supergiants: When a main sequence star, less massive than eight times the Sun, depletes its core hydrogen, it undergoes significant changes.

- The core contracts, increasing temperature and pressure, igniting helium fusion.
- Simultaneously, hydrogen fusion shifts to the outer layers, causing the star to expand into a red giant. Our Sun is destined to become a red giant in the distant future.

Planetary Nebulae: Red giants become unstable, pulsating and periodically expelling portions of their outer atmosphere.

- Eventually, these outer layers are completely blown away, forming an expanding cloud of dust and gas known as a planetary nebula.

White Dwarfs: Average-sized stars like our Sun, near the end of their lives, shed their outer layers, revealing their hot, dense cores. These cores become white dwarfs.

- White dwarfs are incredibly hot, resembling glowing cinders despite being stellar remnants. They are supported by electron degeneracy pressure, preventing complete gravitational collapse.

Chandrasekhar Limit

The Chandrasekhar Limit, named after Subrahmanyan Chandrasekhar, sets the maximum mass for a white dwarf at 1.4 solar masses. Stars exceeding this limit are destined to become neutron stars or black holes.

Nova Explosions Vs Supernova Explosions

Aspect	Nova Explosions	Supernova Explosions
Definition	A **thermonuclear explosion** on the surface of a **white dwarf** in a binary system.	The **death of a massive star** resulting in an **extremely energetic explosion.**
Cause	Accumulation of **hydrogen** from a companion star on a white dwarf, which leads to ignition.	The core of a **massive star** collapses, or a **binary system** undergoes a catastrophic event.
Energy Release	**Moderate energy** release, increasing brightness for a short period.	**Immense energy** release, with a massive brightness increase.
Frequency	Can occur **repeatedly** in the same star system, with multiple nova events.	**One-time event;** the star dies after the explosion.
Resulting Objects	**White dwarf** remains intact, continuing its life cycle.	Results in the formation of a **neutron star** or a **black hole,** depending on the star's mass.

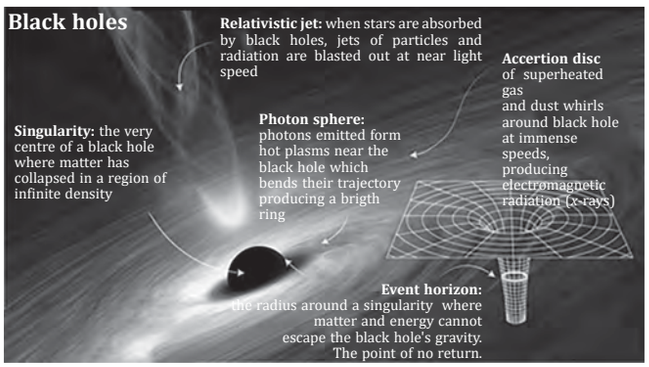
Neutron Stars: If the core of a supernova has a mass between 1.4 and 3 solar masses, it collapses further, forming a neutron star. These incredibly dense objects are composed primarily of neutrons, packed together tightly by immense gravity.

- Neutron stars often exist in binary systems, where their strong gravitational fields can accrete material from companion stars. This accretion process can lead to the emission of X-rays.
- **Pulsars:** The rapidly rotating magnetic fields of neutron stars can produce beams of radiation that are observed as pulsars.

- **Magnetars:** A subset of neutron stars known as magnetars have exceptionally strong magnetic fields, billions of times stronger than Earth's. These powerful fields can produce intense bursts of X-rays and gamma rays.

Black Holes: When a massive star's core collapses to a mass greater than three times that of the Sun, it transforms into a black hole. These incredibly dense objects have such intense gravity that nothing, not even light, can escape their grasp.

- **Black holes are divided into three types:** stellar-mass black holes (also known as unicorns), Supermassive black holes, and Intermediate-mass black holes.


Black holes
Relativistic jet: when stars are absorbed by black holes, jets of particles and radiation are blasted out at near light speed
Accertion disc of superheated gas and dust whirls around black hole at immense speeds, producing electromagnetic radiation (x-rays)
Singularity: the very centre of a black hole where matter has collapsed in a region of infinite density
Photon sphere: photons emitted form hot plasms near the black hole which bends their trajectory producing a brigth ring
Event horizon: the radius around a singularity where matter and energy cannot escape the black hole's gravity. The point of no return.

KEY TERMS

Planet

The most recent definition of a planet was adopted by the International Astronomical Union in 2006. It says a planet must do three things:

- It must orbit a star (in our cosmic neighborhood, the Sun).
- It must be big enough to have enough gravity to force it into a spherical shape.
- It must be big enough that its gravity cleared away any other objects of a similar size near its orbit around the Sun.

Dwarf Planet

- As per the **International Astronomical Union (IAU):** A dwarf planet is a celestial body that circles the sun, has enough mass to assume a roughly round shape, has not cleared the neighborhood surrounding its orbit, and is not a moon.
- Ceres, Pluto, Eris, Makemake, and Haumea are the first five dwarf planets discovered.

Pluto was reclassified as a "dwarf planet" by the International Astronomical Union (IAU) in 2006 due to its inability to clear its orbit of other debri.

Kuiper Belt

- The Kuiper Belt is a ring of icy rocks & dust bodies just outside of Neptune's orbit, known as Kuiper belt objects or trans-neptunians.
- Pluto is the largest known Kuiper Belt Object instead of the 9th planet of our Solar system. There are bits of rock and ice, comets, and dwarf planets.

Asteroid Belt

- Asteroids are remnants of planetary formation mainly composed of refractory rocky and metallic minerals and some ice, that circle the sun in a zone lying between Mars and Jupiter.
- The circular chain of asteroids is called the asteroid belt or main asteroid belt.

Ploonets

- A Ploonet is a moon that escapes its planet's gravity and begins to orbit the star directly — essentially becoming a "planet-like object".
- The researchers explain that the angular momentum between the planet and its moon results in the moon escaping the gravitational pull of its parent planet.

Goldilocks Zone

- The 'Goldilocks Zone,' or habitable zone – 'the region around the star where a planet could sustain liquid water on its surface'.
- Our Earth is in the Sun's Goldilocks zone.

Astronomical Distance

- For measuring these extremely large distances, we use two astronomical units, the light year and the parsec.
- A light year is defined as the distance travelled by light in one year. Astronomical distances are measured in light-years because Speed of light is always the same.

Asteroids

- Big chunks of rocks float through space and orbit the sun, mostly found in the main asteroid belt i.e., between Mars and Jupiter.
- The biggest one is Ceres (940 km wide), twice as big as the Grand Canyon. [Note: Ceres is a dwarf planet, not classified as asteroid anymore]

Meteoroid

- Smaller rock pieces that break off from an asteroid, float through interplanetary space.
- Can be as small as grain of sand or as large as a meter across.

Meteor

- When a meteoroid enters the earth's atmosphere, it begins to burn up and falls to the ground.

- This burning trail is known as meteor or falling stars/ shooting star.

Meteorite

- If a meteoroid rock doesn't completely burn up as it falls to Earth- the rock left behind is called a meteorite.

Comets

- Comets are frozen leftovers from the formation of the solar system composed of dust, rock and ices, ranging from few miles to tens of miles wide.
- Orbits closer to the sun, they heat up and spew gases and dust into a glowing head visible in the atmosphere.
- Comets have highly elliptical orbits, unlike planets which have near-circular orbits.

Van Allen Radiation Belts

- It is a zone of energetic charged particles, most of which originate from the solar wind.
- The particles are captured by and held around a planet by that planet's magnetic field.
- These are intense over the Equator and are Weaker over the poles.
- One of the consequences of the belts is the aurora borealis and aurora australis.

Space Debris

Space junk, also known as space debris, refers to any man-made objects left in orbit around Earth.

- This includes large items like defunct satellites and smaller debris such as paint flecks or fragments from rocket launches.
- The majority of space junk is found in Low Earth Orbit (LEO), within 2,000 kilometers of the Earth's surface.
- **Kessler Syndrome:** The runaway effect of debris from one collision causing another, generating more debris and further collisions is called the Kessler Syndrome.

Space Debris Removal Initiatives

International Initiative	Indian Initiative
❖ Committee on Peaceful Uses of Outer Space (COPUOS) (1958)	❖ ISRO System for Safe & Sustainable Operations Management (IS4OM) (2022)
❖ Clean Space Initiative (ESA, 2012)	❖ Project Netra (Network for Space Object Tracking and Analysis)
❖ Liability Convention of 1972	❖ ISRO SSA (Space Situational Awareness) Control Centre (2020)
❖ Outer Space Treaty (1967)	

ORBITS

An orbit is the curved path that an object in space (such as a star, planet, moon, asteroid or spacecraft) takes around another object due to gravity.

Types of Orbit based on Altitude

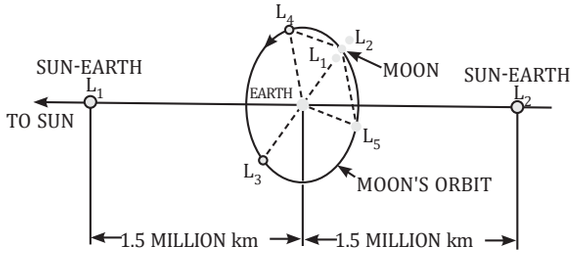
Orbit Name	Altitude (km)	Orbital Period	Applications
High Earth Orbit (HEO)	>35,786	24 hours (geosynchronous)	Communication satellites (GSAT series), weather monitoring {NSAT and GSAT satellites use C, Ku, and Ka bands for communication, whereas the MF (Medium Frequency) band is not used for satellite communication.**(RAS 2021)**}
Medium Earth Orbit (MEO)	2,000 - 35,780	12 hours	Global Positioning Systems (GPS, GLONASS, Galileo)
Low Earth Orbit (LEO)	160 - 2,000	90 minutes	Satellite imaging, Earth observation, communication satellites (constellations), International Space Station (ISS)

Types of Orbit based on Functionality

Orbit Type	Description	Altitude (km)	Orbital Period	Applications
Geosynchronous Orbit (GEO)	A high Earth orbit where the satellite appears stationary above a fixed point on Earth.	35,786	24 hours	Weather monitoring, communication, navigation. e..g. INSAT and GSAT series

Polar Orbit	A low Earth orbit passing over Earth's poles.	200-1,000	15 - 16 orbits per day	Earth observation, remote sensing. e.g. Cartosat series of ISRO
Sun-Synchronous Orbit (SSO)	A polar orbit where the satellite passes over the same point on Earth at the same local time.	600-800	~14 orbits per day	Climate change studies, weather prediction, resource management
Transfer Orbits	Intermediate orbits used to move satellites between other orbits.	Varies		Used to transition between different orbits

Lagrange Point



- A Lagrange point is a position in space where the gravitational forces of two large celestial bodies (such as the Earth and the Moon or the Earth and the Sun) and the centrifugal force of an object placed there balance each other, allowing the object to remain in a stable or semi-stable position relative to the two bodies.
  - These points, named after the mathematician Joseph-Louis Lagrange, offer stable positions for spacecraft to maintain their relative position to the Earth and Sun.

Lagrange Point	Location	Purpose
L1	Between Earth and Sun	Observing the Sun (e.g., Aditya-L1 mission)
L2	Behind Earth, opposite the Sun	Observing the larger universe (e.g., James Webb Space Telescope)
L3, L4, and L5	Equilateral triangles with Earth and Sun	Potential for future missions and observations

Halo Orbit: Halo orbits are three-dimensional, periodic orbits around Lagrange points in a two-body system like Earth-Sun or Earth-Moon.

- It is commonly linked with L1, L2, and L3 Lagrange points, where the gravitational forces of two large bodies and centrifugal force balance each other.

SATELLITE

Satellites are celestial bodies that orbit larger bodies, such as planets. They can be natural, like Earth's moon, or artificial, launched into space for specific purposes. Artificial satellites are placed in various orbits using rockets and equipped with instruments for a wide range of applications. An artificial satellite orbiting around the Earth does not fall down. This is so because the attraction of Earth Provides the necessary acceleration for its motion.

- **Functions of Satellites:** Earth Observation, Communication, Navigation.
- **Application:** For the measurement/ estimation of Chlorophyll content in the vegetation of a specific location, Greenhouse gas emissions from rice paddies of a specific location and Land surface temperatures of a specific location, etc.
- Russia (formerly the Soviet Union) was the first country to launch an artificial satellite, successfully sending Sputnik 1 into space on October 4, 1957. (RAS 2013)

Type of Satellite	Purpose	Examples
Earth Observation Satellites (EOS)	Long-term observation of Earth's atmosphere, biosphere, lithosphere, and oceans, Weather forecasting, climate monitoring, disaster warning	Cartosat, Oceansat, Resourcesat, EOS-04
Navigation Satellites	Geospatial services, navigation, and positioning	GPS, GLONASS, Galileo, BeiDou, NavIC

Communication Satellites	Telecommunication, broadcasting, internet services	INSAT, Starlink, OneWeb, GSAT31

IRNSS-NavIC

- The Navigation with Indian Constellation (NavIC) satellite system is an autonomous regional navigation satellite system that provides location data in the Indian area and 1500 kilometers surrounding the Indian landmass.
- IRNSS would offer two types of services Standard Positioning Services, which would be available to all users, and Restricted Services, which would only be available to permitted users.
- There are seven satellites in all. **Three** will be Geosynchronous above the Indian Ocean and **four** will be Geostationary

SPACE ORGANISATIONS IN INDIA

Organization	Description
Indian Space Research Organization (ISRO)	❖ Government of India's nodal agency for space research, under the Department of Space (DOS). ❖ Founded in 1969, headquartered in Bengaluru, Karnataka. ❖ Developed and launched India's own launch vehicles, PSLV and GSLV.
Indian National Space Promotion and Authorization Centre (IN-SPACe)	❖ Government body established in 2020 to promote private sector participation in space activities. ❖ Facilitates partnerships between ISRO and private companies. ❖ Regulates and encourages Indian industry and startups in satellite construction, rocket development, and commercial launch services.
New Space India Limited (NSIL)	❖ ISRO's commercial arm, wholly owned by the Government of India. ❖ Collaborates with IN-SPACe to enable industry consortiums to undertake some of ISRO's responsibilities. ❖ Provides commercial services such as satellite launch, ground station services, and data analysis.
Antrix Corporation	❖ ISRO's commercial arm, founded in 1992. ❖ Promotes and commercializes space products, services, and technology transfer.

Key Institutes and Centers Associated with ISRO (RAS 2018)

Institute Name	Location	Key Function / Feature
Indian Institute of Space Science and Technology (IIST)	**Thiruvananthapuram, Kerala**	Dedicated institute for education and research in space science.
Physical Research Laboratory (PRL)	**Ahmedabad, Gujarat**	Considered the 'Cradle' for space and allied sciences.
Indian Institute of Remote Sensing (IIRS)	**Dehradun, Uttarakhand**	Training and education in the field of Remote Sensing.
National Remote Sensing Centre (NRSC)	**Hyderabad, Telangana**	Management of satellite data and monitoring of natural resources.
Space Applications Centre (SAC)	**Ahmedabad, Gujarat**	Development of payloads and communication systems for satellites.
Liquid Propulsion Systems Centre (LPSC)	**Valiyamala, Thiruvananthapuram**	Development of liquid fuel engines for satellites and rockets.
Vikram Sarabhai Space Centre (VSSC)	**Thiruvananthapuram, Kerala**	ISRO's premier rocket and launch vehicle development center.
Satish Dhawan Space Centre (SDSC)	**Sriharikota, Andhra Pradesh**	India's main spaceport and launch center.

Centre for Space Science and Technology Education in Asia and the Pacific (CSSTEAP)	**Dehradun, Uttarakhand**	International training center affiliated with the United Nations (UN).
ISRO Propulsion Complex (IPRC)	**Mahendragiri, Tamil Nadu**	Testing and assembly of rocket engines.
North Eastern Space Applications Centre (NE-SAC)	**Umiam, Meghalaya**	Utilization of space technology for the development of the North-Eastern region.
U.R. Rao Satellite Centre (URSC)	**Bengaluru, Karnataka**	Main center for the design and construction of Indian satellites.

Space Startups in India

New Startup Name	Established	Focus
Dhruva Space Private Limited	2012	Satellite manufacturing and related services
Bellatrix Aerospace	2015	Satellite propulsion systems and technologies
Aadyah Aerospace	2016	Satellite design, manufacturing, launch vehicles, and propulsion
Agnikul Cosmos	2017	Developing a small satellite launch vehicle
Manastu Space	2017	Green technology for space, including alternative fuels, refueling stations, and deorbiting solutions
Skyroot Aerospace	2018	Developing satellite launch vehicles and associated technologies
Satellize	2018	Satellite communication and related services
Pixxel	2019	Building a constellation of Earth observation satellites

TYPES OF LAUNCH VEHICLES BY ISRO

A launch vehicle is a **rocket-powered vehicle** that transports a spacecraft **beyond the Earth's atmosphere**, either into orbit around the Earth or to another destination in outer space.

Launch Vehicles of India

Launch Vehicle	Stages	Payload Capacity	Orbits	Description
Small Satellite Launch Vehicle (SSLV)	3 (solid, solid, liquid)	10-500 kg	Low Earth Orbit (LEO)	India's smallest launch vehicle, designed for launching small satellites. Successfully launched its first mission in 2022. (RAS 2016)
Polar Satellite Launch Vehicle (PSLV)	4 (solid, liquid, liquid, solid)	1,750 kg (LEO), 1,425 kg (GTO)	Sun-Synchronous Polar Orbit, Geosynchronous/ Geostationary Orbit	India's workhorse launch vehicle, successfully launched numerous satellites including Chandrayaan-1 and several communication and remote sensing satellites.
Geosynchronous Satellite Launch Vehicle (GSLV) Mark II	3 (solid, liquid, cryogenic)	2,250 kg (GTO), 6 tonnes (LEO)	Geosynchronous Transfer Orbit, Low Earth Orbit	Capable of launching heavy satellites into geostationary orbit, using a cryogenic upper stage. Successfully launched communication satellites.
Geosynchronous Satellite Launch Vehicle Mk-III (LVM3)	3 (liquid, solid, cryogenic)	4 tonnes (GTO), 8 tonnes (LEO)	Geosynchronous Transfer Orbit, Low Earth Orbit	India's most powerful launch vehicle, capable of launching heavy satellites and supporting human spaceflight missions. Successfully Chandrayaan-2 Chandrayaan-3 and Gaganyaan.

ROCKET TECHNOLOGY

Sounding Rockets

Sounding rockets are single- or two-stage solid-propellant rockets designed to carry scientific instruments into the upper atmosphere for research purposes. They provide valuable data on atmospheric conditions, ionospheric studies, and other space-related phenomena.

Early Developments

- **M-100 (Russia) and Centaure (France):** The first sounding rockets were developed by Russia and France in the early 1960s.
- **ISRO's Beginnings:** India launched its first sounding rocket, the **Nike-Apache**, in 1963 from Thumba, near Thiruvananthapuram, marking the beginning of its space program.

The Rohini Sounding Rocket (RSR) Program:

- **Consolidation:** Established in 1975, the RSR program consolidated all sounding rocket activities in India.
- **Payloads:** These rockets carried various payloads ranging from 8 to 100 kg, including instruments to study the atmosphere, ionosphere, and solar radiation.

GaAs (Gallium Arsenide) Solar Cells (RAS 2018)

Bharat Electronics Limited (BEL), in collaboration with ISRO, manufactures GaAs (Gallium Arsenide) Solar Cells for satellites and other space applications.

Key Features of GaAs Solar Cells

- GaAs (Gallium Arsenide) is a III-V semiconductor material widely used in photovoltaic (solar cell) technology.
- It offers high conversion efficiency and excellent performance in space environments.
- It has high electron mobility and high saturated electron velocity, enabling operation at frequencies exceeding 250 GHz.
- It is highly resistant to radiation and extreme temperatures, making it ideal for satellites and spacecraft.
- Applications:Satellites, Spacecraft, Communication systems, High-frequency electronic devices

Rocket Fuel

- Rocket fuel is the propellant used to provide the thrust required for a rocket to take off and propel through the atmosphere and into space.
- The Indian Space Research Organisation (ISRO) is using the very poisonous and corrosive fuel UDMH (Unsymmetrical Di-Methyl Hydrazine), combined with the oxidiser nitrogen Tetroxide. This is referred to as a "dirty combo."

Propellant Used in Rocket

- The propellant is a chemical mixture that comprises a fuel and an oxidizer that is burned to provide thrust in rockets.
- For propulsion, fuel is a substance that burns when mixed with an oxidizer.
  - The oxidizer is a substance that releases oxygen in order to be combined with a fuel. The mixture ratio is the proportion of oxidizer to fuel.
  - The condition of a propellant is classified as liquid, solid, or hybrid.
- **Liquid Propellant:** The fuel and oxidizer are stored separately in a liquid propellant rocket and delivered to a combustion chamber by a system of pipes, valves, and turbopumps, where they are mixed and burned to produce thrust.
- Cryogenic propellants are liquefied gases kept at extremely low temperatures, with the most common fuel being liquid hydrogen (LH_2) and the oxidizer being liquid oxygen (LO_2 or LOX).

Cryogenic Engine

- A cryogenic rocket engine uses a cryogenic fuel or oxidizer, which means the fuel or oxidizer (or both) are gases that have been liquefied and kept at extremely low temperatures.
- In comparison to solid and earth-storable liquid propellant rocket stages, cryogenic rocket stages are more efficient and produce greater thrust per kilogram of propellant burned.

Air Breathing Engines

- In the burning of fuel, air-breathing engines utilize oxygen from the environment. The turbojet, turboprop, ramjet, and pulse-jet are among them.

Speed Range	Mach Number
Subsonic	< 0.8
Transonic	0.8 - 1.2
Supersonic	1.2 - 5
Hypersonic	5 - 10
High-hypersonic	10 - 25

- **Types of Air Breathing Engines:**
  - **Ramjet:** A ramjet is a type of air-breathing jet engine that compresses incoming air for combustion without the use of a revolving compressor.
  - **Scramjet:** A scramjet engine is superior to a ramjet engine because it can run at hypersonic speeds while still allowing supersonic combustion. e.g. Scramjet Engine Technology Demonstrator (Scramjet-TD), Hypersonic Technology Demonstrator Vehicle (HSTDV) etc.
  - **Dual Mode Ramjet** (DMRJ) is a kind of jet engine that converts from a ramjet to a scramjet over the Mach 4-8 range, allowing it to function efficiently in both subsonic and supersonic combustion modes. e.g. Air Breathing Propulsion System (ABPS)

ISRO SATELITES

Type	Satellite Name	Purpose
Communication	CMS-01	Launched in 2017 for various communication services, including broadband connectivity and satellite newsgathering.
	GSAT 7A (Angry Bird)	Launched in 2018, provides broadband connectivity to remote areas of India.
	GSAT-11	Launched in 2018, offers high-throughput broadband services for various applications.
Earth Observation	OCEANSAT-3	Launched in 2022, studies oceans and atmosphere, providing data for weather forecasting, climate monitoring, and natural resource management.
	RISAT-2	Radar imaging satellite launched in 2019, used for Earth observation, disaster management, and agricultural applications.
Satellite Navigation	NAVIC (Navigation using Indian Constellation)	India's regional navigation satellite system, providing accurate positioning, navigation, and timing services to users in India and the surrounding region.
Sun Studies	ADITYA L1	Solar mission launched in 2023 to study the Sun's outer atmosphere and solar wind. Solar mission placed at the L1 Lagrange point to observe the Sun's corona and other aspects of solar activity.

ISRO'S INTERPLANETARY MISSION

Mars Orbiter Mission (MOM) (RAS 2013)

- **Mission:** India's first interplanetary space mission.
- **Launch:** November 5, 2013, aboard PSLV-C25.
- **Significance:** Made India the first Asian country and the fourth in the world to reach Mars in 2014.
- **Objectives:** Study the Martian atmosphere, surface features, mineralogy, and morphology. Develop technologies for interplanetary missions.

Venus: Shukrayaan-1

- **Mission:** India's first planned mission to Venus, designed to study the planet's surface, atmosphere, and geological features.
- **Launch Vehicle:** GSLV Mk II rocket.
- **Orbiter:** A spacecraft of approximately 2500 kg will orbit Venus to gather data.
- **Objectives:** Understand Venus's climate and its evolution, Explore signs of active volcanoes and seismic activity.

India's Missions to Moon

- **Chandrayaan-1 (RAS 2016)**
  - India's first mission to the Moon, was launched in 2008.
  - Chandrayaan-1 reached the lunar orbit 21 days after its launch and after making 3400 orbits around the Moon and transmitting data.
  - In late November 2008, Chandrayaan-1 began experiencing abnormally high temperatures.
  - The last contact with Chandrayaan-1 was on August 28, 2009.
- **Chandrayaan-2**
  - The failure of Chandrayaan-2, India's second mission to the Moon, to make a soft-landing on the lunar surface had led to much disappointment.
  - The lander and rover malfunctioned in the final moments and crash-landed, getting destroyed in the process
  - But that did not mean the entire mission had been wasted. The Orbiter part of the mission has been functioning normally.
- **Chandrayaan-3**
  - The Chandrayaan-3 mission consists of a lander module, a propulsion module, and a rover.
  - The Chandrayaan-3 Lander has solar panels on four sides, instead of only two in Chandrayaan-2.

- Chandrayaan-3 is a follow-on mission to Chandrayaan-2 to demonstrate end-to-end capability in safe landing and roving on the lunar surface.
- The spacecraft departed from the Satish Dhawan Space Centre in Sriharikota on July 14, 2023, and smoothly entered lunar orbit by August 5, 2023.
- The lander achieved a flawless touchdown near the lunar south pole on August 23, 2023.
- The total weight of Chandrayaan-3 is 3,900 kg, with the propulsion module weighing 2,148 kg and the lander and the rover both weighing 1,752 kg.

Lunar Probe Exploration Mission (LUPEX)/ Chandrayaan-5

- **Joint Mission:** A collaborative venture between the Indian Space Research Organization (ISRO) and the Japan Aerospace Exploration Agency (JAXA).
- **Objective:** To explore the Moon's south polar region, focusing on the presence of water and other resources.
- **Launch Vehicle:** Japan's H3 rocket is scheduled to launch the mission.
- **Timeline:** Targeted for launch in 2027-28.

Key Features:

- **Lander and Rover:** LUPEX will consist of a lander and a rover, developed by ISRO and JAXA respectively.
- **Scientific Instruments:** The rover will carry instruments to measure the water content of lunar regolith, drill and sample lunar materials, and conduct other scientific experiments.
- **International Collaboration:** The mission will also include instruments from NASA and the European Space Agency (ESA).
- **Significance:** Water on the Moon, Future Exploration, Technological Advancement.

OTHER IMPORTANT PROJECTS OF ISRO

Gaganyaan Mission

Gaganyaan is an ambitious Indian space mission aimed at sending humans into orbit. It consists of three planned flights: two unmanned missions and one crewed mission.

Objectives: Gaganyaan aims to demonstrate India's capability in human spaceflight and conduct scientific experiments in microgravity.

- India's astronauts-designated for Gaganyaan: Group Captain Prasanth Balakrishnan Nair, Group Captain Ajit Krishnan, Group Captain Angad Pratap, and Wing Commander Shubhanshu Shukla

Key Details:

- **Launch Vehicle:** The GSLV Mk III (Launch Vehicle Mark-3) is the powerful rocket chosen to launch Gaganyaan.
- **Orbital Module:** The spacecraft carrying the astronauts will be the Orbital Module.
- **Mission Duration:** The crewed mission will orbit Earth at a low-earth-orbit altitude of 300-400 kilometers for 5-7 days.
- **Astronauts:** Three Indian astronauts, including a woman, will participate in the crewed mission.

Mission Preparatory Tests

- **Integrated Air Drop Test (IADT):** Verifies the functionality of parachute and deceleration mechanisms.
- **Test Vehicle Missions (TV):** Assesses abort and launch system performance.
- **Pad Abort Test (PAT):** Evaluates the crew module's safety across different altitudes.
- **Water Survival Test Facility (WSTF):** Conducts recovery trials with the support of the Navy.

GEMINI: Gagan Enabled Mariner's Instrument for Navigation and Information

The GEMINI device, developed by ISRO, is a portable satellite receiver that can be used for communication in areas beyond the reach of traditional cellular networks. It offers a valuable tool for disaster management, especially in remote regions or during emergencies.

Key Features:

- **Satellite Connectivity:** GEMINI connects to ISRO's satellites, enabling communication over long distances.
- **Wide Coverage:** The device can transmit signals up to 300 nautical miles, extending communication reach beyond the limitations of cellular networks.
- **Disaster Management:** GEMINI is particularly useful during storms, strong seas, or tsunamis, providing a reliable communication channel in emergency situations.

GAGAN: India's Global Navigation System

- GAGAN (GPS Aided GEO Augmented Navigation) is India's Satellite-Based Augmentation System, jointly developed by ISRO and AAI, to enhance GPS accuracy and integrity, especially for civil aviation. It improves air traffic management and flight safety across Indian airspace, while also supporting maritime navigation, railways, road transport, precision agriculture, and disaster management.
- **Satellite Network:** GAGAN relies on ISRO's GSAT satellites for precise positioning and navigation services.

Limitation: While GAGAN offers accurate positioning, it currently only supports one-way communication. This means that users cannot make calls using GAGAN.

Mission Shakti

On March 27, 2019, India successfully conducted its first Anti-Satellite (ASAT) missile test, named **Mission Shakti**.

- This mission, carried out by the Defence Research and Development Organisation (DRDO) from Dr. APJ Abdul Kalam Island in Odisha, demonstrated India's capability to develop and deploy a complex missile system with potential applications in space warfare.

XPoSat

- **Purpose:** To study the polarization of X-ray emission from celestial sources, providing insights into their radiation mechanisms and geometry.
- **Launch:** Successfully launched on January 1, 2024, aboard the PSLV-C58 rocket.
- **Orbit:** Low Earth orbit at an altitude of approximately 650 km.
- **Mission Duration:** Expected to operate for at least five years.

Scientific Payloads

1. **POLIX (Polarimeter Instrument in X-rays):**
   - Designed to measure the polarization of X-rays in the medium energy range (8-30 keV).
   - Utilizes a collimator and scatterer to filter and analyze X-ray photons.
   - Will observe a few tens of astronomical sources.
2. **XSPECT (X-ray Spectroscopy and Timing):**
   - Provides high-resolution spectroscopy and fast timing capabilities in the soft X-ray energy band (0.8-15 keV).
   - Will study a variety of sources, including X-ray pulsars, black hole binaries, neutron stars, and active galactic nuclei (AGNs).

IceCube

The IceCube Neutrino Observatory is the first detector of this type, designed for observing the cosmos from deep within the South Pole ice. An international group of scientists responsible for the scientific research makes up the IceCube Collaboration

Optical illusions

Size of the sun at dusk , Colour of the sun at dawn and Twinkle of stars in the sky are examples of optical illusions

NISAR Mission (NASA-ISRO Synthetic Aperture Radar)

- **Purpose:** To study Earth's surface changes, monitor natural hazards, analyze climate patterns, and understand dynamic ecosystems.
- **Collaboration:** A joint mission between NASA and ISRO (Indian Space Research Organization).
- **Launch:** July 30, 2025
- **Mission Life:** 5 Years.
- **Category:** Earth observation satellite
- **Launch Vehicle:** GSLV Mk II derivative (LVM-2 variant)
- **Launch Site:** Satish Dhawan Space Center, ISRO
- **Orbit:** Sun-synchronous orbit (LEO) at an altitude of 747 km
- **Radar Instruments:**
  - L-band Synthetic Aperture Radar (L-SAR) provided by NASA. It penetrates forest canopy, ice, and soil, useful for biomass and deformation studies.
  - S-band Synthetic Aperture Radar (S-SAR) provided by ISRO. Better for monitoring crops, wetlands, and other surface-level features.

IMPORTANT PERSONALITIES

Vikram Sarabhai

Dr. Vikram Sarabhai was a renowned Indian physicist and astronomer who played a pivotal role in the development of India's space program. Vikram Sarabhai is considered the **Father of the Indian Space Program.**

- **Founding of the Physical Research Laboratory (PRL):**
  - Established PRL in Ahmedabad in 1947.
  - Focused on research in cosmic rays, astrophysics, and other related fields.
- **Indian National Committee for Space Research (INCOSPAR):**
  - Convinced the Indian government to establish INCOSPAR in 1962.
  - Served as its first chairman.
- **Indian Space Research Organisation (ISRO):**
  - Restructured INCOSPAR into ISRO in 1969.

- Led ISRO's early development and oversaw its significant achievements.

- **Key Contributions to Indian Space Program:**
  - Launched India's first satellite, Aryabhata, in 1975.
  - Played a crucial role in developing India's satellite communication and remote sensing capabilities.
- **Other Achievements:**
  - Established the Indian Institute of Management, Ahmedabad (IIMA).
  - Served as the chairman of the Atomic Energy Commission of India.
  - Received numerous awards and honors, including the Padma Bhushan and Padma Vibhushan.

S. Somanath

S. Somanath, an eminent rocket scientist has been appointed as the **Chairman of the Indian Space Research Organisation (ISRO**) and the Space Secretary.

Contributions

- He has played a major role in the development of the **Polar Satellite Launch Vehicle (PSLV)** and the **Geosynchronous Satellite Launch Vehicle Mk-III (GSLV Mk-III).**
- He joined the **GSLV Mk-III** project in 2003, and served as Project Director from 2010 to 2014.
- Later on, he contributed to the development of the indigenous **cryogenic stages for the GSLV.**

NASA INITIATIVES

Great Observatory Programme

The Great Observatories Program was a series of four major space-based (The Hubble, Compton, Chandra, and Spitzer telescopes) launched by NASA between 1990 and 2003. Each telescope was designed to observe a specific range of the electromagnetic spectrum, providing a comprehensive view of the universe.

Telescope Name	Wavelength Range	Purpose	Key Discoveries
Hubble Space Telescope (HST)	Visible and ultraviolet light	Imaging distant galaxies, stars, and nebulae	Age of the universe, evidence for dark energy, formation of stars and galaxies
Compton Gamma Ray Observatory (CGRO)	Gamma rays	Studying high-energy astronomical phenomena	New types of gamma-ray sources (gamma-ray bursts, active galactic nuclei)
Chandra X-ray Observatory (CXO)	X-rays	Observing hot, high-energy objects	Detailed images of hot gas surrounding galaxies and clusters
Spitzer Space Telescope (SST)	Infrared	Observing cool, dusty objects	Exoplanets, galaxy formation, star-forming regions

Perseverance Rover Mission on Mars

NASA's Perseverance rover, part of the Mars 2020 mission, landed at Jezero Crater on Mars in February 2021. Its primary objectives include:

- **Astrobiology:** Searching for signs of ancient microbial life.
- **Sample Collection:** Gathering rock and regolith samples for potential return to Earth.

  The rover is also accompanied by the Ingenuity helicopter, which successfully completed the first powered, controlled flight on another planet.

Parker Solar Probe

- **Mission:** NASA's Parker Solar Probe is a groundbreaking mission designed to study the Sun's outer atmosphere, the corona.
- **Launch:** Launched in 2018, it's the first spacecraft to directly sample particles and magnetic fields from the corona.
- **Objective:** To understand the mechanisms that heat the corona and accelerate the solar wind.

Significance: Observations into the Sun's behavior and its influence on the solar system, understanding of solar physics, astrophysics, and space weather.

Lucy Mission

- **Objective:** To study Jupiter's Trojan asteroids, remnants of our solar system's formation.
- **Launch:** Launched in 2021 on a United Launch Alliance Atlas V rocket.
- **Trajectory:** Will utilize Earth's gravity for a slingshot effect, allowing it to reach the Trojan asteroids.

Double Asteroid Redirection Test (DART) Mission

- **Purpose:** To test a spacecraft's ability to intentionally collide with an asteroid and alter its trajectory, demonstrating a potential method for planetary defense against potential asteroid threats.

- **Target:** The Didymos binary asteroid system, consisting of a larger asteroid (Didymos) and a smaller moonlet (Dimorphos).
- **Launch:** Launched in November 2021.
- **Impact:** Successfully collided with Dimorphos in September 2022, altering its orbit.

INTERNATIONAL EFFORTS

Missions to Moon

Early Robotic Missions:

- **Luna 2 (Soviet Union):** The first spacecraft to reach the Moon's surface in 1959.
- **Luna 9 (Soviet Union):** The first spacecraft to achieve a controlled soft landing on the Moon in 1966.
- **Luna 10 (Soviet Union):** The first spacecraft to enter lunar orbit in 1966.

Crewed Missions: Apollo Program (United States)

- **Apollo 8:** The first crewed mission to orbit the Moon in 1968.
- **Apollo 11:** The historic mission that saw Neil Armstrong and Buzz Aldrin become the first humans to walk on the Moon in July 1969.
- **Total Crewed Missions:** A total of twelve astronauts have walked on the Moon, with the last mission being Apollo 17 in 1972.

Recent Developments: Artemis Program

- **NASA's Artemis Program:** Aims to land the first woman and first person of color on the Moon, using innovative technologies to explore more of the lunar surface.
- Space agencies involved in the Artemis programme: NASA, Canadian Space Agency, European Space Agency, Japan Aerospace Exploration Agency

Missions to Mars

- **Soviet Probes:** The Soviet Union initiated Mars exploration efforts in the 1960s with a series of probes.
- **Mariner 9 (NASA):** In 1971, Mariner 9 became the first spacecraft to successfully orbit Mars, providing detailed images of the planet's surface.
- **Mars Global Surveyor (NASA):** Launched in 1997, this orbiter conducted a comprehensive mapping mission of Mars, completing its primary objectives in early 2001.
- **Mars Pathfinder (NASA):** Also launched in 1997, this lander carried the Sojourner rover, which explored the Martian surface and collected data.
- **Mars Odyssey (NASA):** Entered Mars orbit in 2001, focusing on studying the planet's mineral composition and searching for water ice.

Voyager Mission

The Voyager missions, launched by NASA in 1977, hold a significant place in space exploration history.

- These twin spacecraft, Voyager 1 and Voyager 2, embarked on a journey to explore the outer reaches of our solar system.

Initial Mission Objectives: Designed for close-up studies of Jupiter and Saturn, focusing on their atmospheres, rings, and larger moons.

Voyager 2's Achievements

- During flybys, Voyager 2 became the first and only probe to:
  - Study Neptune and Uranus, providing crucial data about these gas giants.
- Voyager 2 also holds the distinction of being:
  - Voyager-2 is second to enter interstellar space.
  - The only spacecraft to have visited all four gas giants (Jupiter, Saturn, Uranus, and Neptune)

Outer Space Governance

Artemis Accords

- **Established:** In 2020 by NASA and seven founding members (Australia, Canada, Italy, Japan, Luxembourg, UAE, UK)
- **Purpose:** Sets common principles for peaceful exploration and use of outer space, Moon, Mars, comets, and asteroids.
- **Foundation:** Based on the Outer Space Treaty of 1967.
- **Signatories:** India is the 27th signatory, joining other nations committed to these principles.

Existing Outer Space Governance Framework

- **UN COPUOS:** Established in 1958 by the UN General Assembly to oversee space exploration and use.
- **UNOOSA:** Supports UN COPUOS in its work.
- **Key Treaties:**
  - **Outer Space Treaty (1967):** Establishes principles for space exploration and use.
  - **Rescue Agreement (1968):** Addresses rescue and return of astronauts and space objects.
  - **Liability Convention (1972):** Establishes liability for damage caused by space objects.
  - **Registration Convention (1976):** Requires registration of space objects.
  - **Moon Agreement (1979):** Governs activities on the Moon and other celestial bodies (India has not ratified).

India is a signatory to all five of these treaties but has not ratified the Moon Agreement.

Bharatiya Antariksh Station

- BAS is India's planned space station for scientific research which will orbit around 400 – 450km above the Earth's surface
- It will have five modules and will be built in phases.
- **Targets:** The first module (the Base Module) will be launch in 2028 and BAS will be operationalized by 2035.

International Space Station

The International Space Station (ISS) is a large, habitable spacecraft orbiting Earth at an altitude of approximately 400 kilometers.

- **Countries:** NASA (United States), Roscosmos (Russia), ESA (Europe), JAXA (Japan), and CSA (Canada).
- **Orbit:** Circles Earth every 90 minutes at a speed of about 28,000 kilometers per hour.
- **Inhabitation:** Continuously inhabited since 2011, serving as a home for astronauts from participating countries.

Significance

- **International Collaboration:** The ISS exemplifies successful international cooperation in space exploration.
- **Space Medicine Research:** Provides insights into the effects of long-duration spaceflight on the human body, aiding in the development of countermeasures for future missions to Mars and the Moon.
- **Scientific Research:** Serves as a platform for conducting various scientific experiments in microgravity, expanding our knowledge of space and its implications for Earth.

Recent Developments

- China has been operating its completed Tiangong Space Station for almost two years now and is looking to expand its capabilities with new modules and spacecraft. The three-module, T-shaped Tiangong space station was fully assembled in November 2022, with the arrival of the Mengtian science module.

Space-Based Internet

Space-based internet, also known as satellite internet, is a type of internet connectivity that utilizes satellites orbiting the Earth to provide broadband services.

- This technology offers a potential solution for areas with limited or no access to traditional internet infrastructure, such as rural regions, remote locations, and developing countries.

Key Technologies:

- **Satellite Constellations:** Large networks of satellites are deployed in low Earth orbit (LEO) or geostationary orbit (GEO) to provide global coverage.
- **Ground Stations:** These stations receive signals from the satellites and transmit them to internet service providers.
- **User Terminals:** Customers require specialized antennas and modems to connect to the satellite network.

Benefits of Space-Based Internet: Global Coverage, High Speed, Low Latency, Disaster Recovery.

Challenges and Considerations: High cost, Weather Interference, Regulatory Challenges.

Prominent Space-Based Internet Projects: Starlink (SpaceX), OneWeb, Amazon Kuiper, JioSpace Fiber (Reliance Jio)

RECENT DEVELOPMENTS IN SPACE TECHNOLOGY

Haven-1: World's First Private Space Station

- **Launch Date:** Early 2027.
- **Launch Vehicle:** SpaceX's **Falcon 9** rocket.
- **Developer:** American space startup **'Vast'**.
- **Orbit:** It will be deployed in Low Earth Orbit (LEO).
- **Commercial Outpost:** It will operate as a private commercial station where research and business activities can be conducted.
- **Collaboration:** This project is supported under NASA's **'Commercial LEO Destinations initiative'**.
- **Initial Phase:** Initially, it will be launched uncrewed. Subsequently, humans will be sent there via the **SpaceX Crew Dragon**.
- **Alternative to ISS:** Amid expectations that the International Space Station (ISS) will retire by 2030, Haven-1 will maintain continuity in space.
- **Space Tourism:** It will lay the foundation for future space tourism and private missions.
- **Technical Testing:** It will serve as an excellent platform for testing new technologies.

Firefly: Pixxel's Hyperspectral Satellite Constellation

This satellite constellation developed by **Pixxel** is a revolutionary step in the field of Earth Observation.

- **Date:** January 15, 2025.
- **Launch Vehicle:** SpaceX's **Falcon-9** rocket.
- **Mission:** Transporter-12 rideshare mission.
- **Developer:** Indian space startup **'Pixxel'**.
- **Resolution:** It is one of the world's highest-resolution commercial hyperspectral satellites (~5-meter resolution).
- **Hyperspectral Technology:** This technology divides the light spectrum into hundreds of narrow bands, providing highly detailed descriptions of the Earth's surface (which standard satellites cannot see).

- **Quantity:** There are a total of **6 satellites** in this constellation, planned to be launched in two phases.
- **Major Applications:**
  - **Agriculture:** Monitoring crop health, early disease detection, and soil quality analysis.
  - **Environment:** Precise identification of deforestation, pollution levels, and oil spills.
  - **Energy and Mining:** Exploration of mineral resources and pipeline monitoring.
  - **Climate Change:** Collection of subtle data on global temperatures and climate change.

India's First Private 'Earth Observation Satellite Constellation': Agreement Between Pixxel and IN-SPACe

The Agreement: On January 21, 2026, 'Allied Orbits', a consortium led by the Bengaluru-based space-tech startup 'Pixxel Space', signed a historic Memorandum of Understanding (MoU) with IN-SPACe.

Project Objective: The main objective of this project is to establish India's first privately built 'National Earth Observation Satellite Constellation'.

Mission 'Sudarshan Chakra': India's Space Defense Shield

- **Name:** Sudarshan Chakra (Space Based Surveillance - Phase 3).
- **Total Cost:** ₹27,000 crores.
- **Total Satellites:** A network of 52 powerful satellites.
- **Objective:** To develop a powerful 'spaceshield' for India.
- **Manufacturing and Launch Strategy:**
  - **ISRO:** Will manufacture 21 satellites.
  - **Private Sector:** 31 satellites will be manufactured by private companies (promoting the PPP model).
- **Timeline:**
  - **First Launch:** Third quarter of 2026.
  - **Full Deployment:** All 52 satellites will be in space within the next 42 months.
- **Launch Site:** New space port at Sriharikota.
- **Technical Capability and Orbit:**
  - **Range:** These satellites will be deployed in various orbits ranging from **500 km (LEO)** up to **36,000 km (GEO)**.
  - **Surveillance:** Being located in different orbits will enable them to maintain **real-time (24x7)** surveillance over every corner of India.
  - **Integration:** This system will work in conjunction with ground-based defense systems (such as **S-400**), which will significantly accelerate the identification of aerial threats and counter-responses.
- **Key Stakeholders of the Mission:** This is an excellent example of inter-agency cooperation:
  - **ISRO:** Technical and launch assistance.
  - **DRDO:** Development of defense equipment and sensors.
  - **Indian Air Force (IAF):** Strategic operation and utilization.

5 Nanotechnology

Definition: Nanotechnology involves the manipulation and engineering of materials at the atomic and molecular scale, typically between **0.1 and 100 nanometers (nm)**. **At this scale, materials exhibit unique physical, chemical, and biological properties** that differ from their bulk counterparts, these properties are governed by quantum physics. Dr. Chintamani Nagesa Ramachandra Rao is considered as the "Father of Indian Nanotechnology" **(RAS 2018/2013)**

Applications of Nanotechnology

1. **Health Sector:**
   - **Technologies:** Targeted drug delivery using liposomes, enhanced imaging with gold nanoparticles, and tissue engineering with nanofibers.
   - **Scientific Principles:** Utilizes nanoscale materials for precise interactions at the cellular level, improving treatment efficacy.
2. **Food Industry:**
   - **Technologies:** Nano-encapsulation for flavours, nanosensors for freshness monitoring, and improved food packaging.
   - **Scientific Principles:** Incorporates nanoscale materials to enhance flavour retention, monitor quality, and provide antimicrobial properties.
3. **Electronics:**
   - **Technologies:** Nanoscale transistors, quantum dot displays, and enhanced lithium-ion batteries.
   - **Scientific Principles:** Leverages nanomaterials to create faster, more efficient electronic components, improving performance and miniaturization.
4. **Energy Efficiency:**
   - **Technologies:** Nanocatalysts for fuel cells, nanotech solar cells, and nanomaterial-based insulation.
   - **Scientific Principles:** Enhances energy conversion and storage through improved reactivity and thermal management at the nanoscale.
5. **Textiles:**
   - **Technologies:** Nano-coatings for waterproof fabrics, antimicrobial textiles, and nanosensors in wearable health monitoring.
   - **Scientific Principles:** Uses nanomaterials to impart desirable properties, such as water resistance and bacteria inhibition, enhancing functionality.
6. **Environment:**
   - **Technologies:** ***Graphene filters*** for water purification, nanoparticles for pollutant cleanup, and photocatalytic materials for degradation of contaminants.
   - **Scientific Principles:** Employs nanoscale materials for efficient pollutant removal and environmental monitoring.
7. **Transportation:**
   - **Technologies:** Lightweight ***nanocomposites*** in car frames and nanomaterials in electric vehicle batteries.
   - **Scientific Principles**: Reduces weight and improves energy efficiency in vehicles through advanced material properties.
8. **Space:**
   - **Technologies:** Radiation protection coatings and lightweight nanocomposites for spacecraft.
   - **Scientific Principles**: Enhances structural integrity and reduces weight, improving spacecraft performance.
9. **Nanorobots:**
   - **Definition:** Nanorobots (or nanobots) are engineered machines at the nanoscale (~50–100 nm) designed for specific functions, such as targeted drug delivery.
   - **Scientific Principles:** Utilize principles of nanotechnology to operate at the cellular level, allowing for precise therapeutic interventions.
10. **Magnetic Hyperthermia Mediated Cancer Therapy:**
    - **Process:** Magnetic nanoparticles (iron oxide) are injected into tumor sites and heated using an alternating magnetic field to target and kill cancer cells while minimizing damage to surrounding healthy tissue.

Quantum Step

- A Quantum Step is a theoretical nanostructure in which electrons experience a sudden change in potential energy due to a discontinuity in the material. It is mainly used to explain quantum confinement effects and electron behavior at interfaces.

Quantum Well (2D Structure) (RAS 2023)

- A Quantum Well is formed when one dimension of a material is reduced to the nano-scale while the other two dimensions remain free. Electrons are confined in one direction but can move freely in the other two directions.

Quantum Wire (1D Structure)

- A Quantum Wire is formed when two dimensions are reduced to the nano-scale and only one dimension remains free. Electrons can move freely in only one direction, leading to unique electrical and optical properties.

Quantum Dot (0D Structure)

- A Quantum Dot is formed when all three dimensions are reduced to the nano-scale. Electrons are confined in all directions, giving rise to discrete energy levels and size-dependent optical properties.**(RAS 2021)**

Government Initiatives to Promote Nanotechnology

- **Mission Nano:** Supports basic research and establishes centers of excellence, focusing on acquiring advanced nanotechnology equipment.
- **Program for Nanotechnology:** Managed by the Department of Information Technology to develop nanoelectronics research and infrastructure.
- **Initiative on Nanoscience and Technology (NSTI):** Established by the Department of Science and Technology to focus on nanomaterials applications, including medicine and drug delivery.
- **Nanotechnology and Science Mission (NSTM):** Aims to promote research and development in nanotechnology, emphasizing human resource development and international collaboration.

Project UNNATI

- **Definition:** Project UNNATI is a capacity-building initiative by the Indian Space Research Organization (ISRO) focused on nanosatellite development.
- **Objective**: Enhance skills of participants from developing nations in nanosatellite building, integration, and testing.
- **Background:** Commemorates the 50th anniversary of the UN Conference on Outer Space Exploration and Peaceful Uses **(UNISPACE+50).**
- **Curriculum:** Includes theoretical and practical training on nanosatellite utility, space debris regulations, design, reliability, quality assurance, and assembly.

MOLECULAR MACHINES

Definition: Molecular machines, or nano machines, are tiny devices at the molecular scale that perform specific **mechanical tasks** when supplied with energy, designed based on molecular biology and chemistry principles.

Core Technology

- Composed of individual molecules or assemblies that can move and change shape in response to stimuli like light, heat, or chemical signals.

Types

- **Molecular Motors:** Convert chemical energy into mechanical motion, akin to biological motors (e.g., ATP synthase).
- **Molecular Switches:** Alter configurations in response to external signals.
- **Molecular Rotors:** Feature rotating components that can move in a controlled manner.

Applications

- **Medicine:** Targeted drug delivery to specific cells or tissues, particularly in cancer treatment.
- **Nanorobotics:** Development of nanorobots for cellular repair and minimally invasive surgeries.
- **Material Science:** Creation of smart materials that adapt their properties based on environmental changes.

Recognition: The **2016 Nobel Prize in Chemistry** was awarded to Jean-Pierre Sauvage, Sir Fraser Stoddart, and Bernard Feringa for their work on molecular machines, highlighting the field's potential.

SUPERCONDUCTIVITY

- **Definition:** Superconductivity is a phenomenon where certain materials exhibit zero **electrical resistance** and expel magnetic fields when cooled below a specific **critical temperature**.
- **Zero Electrical Resistance:** In the superconducting state, materials conduct electric current without any energy loss, resulting in highly efficient electricity transmission.
- **Meissner Effect:** Superconductors expel magnetic fields from their interior, allowing them to repel magnets. This property enables magnetic levitation, which has significant applications in technologies such as maglev trains.
- **Critical Temperature:** Superconductivity occurs only below a specific temperature, known as the critical temperature (Tc). For most traditional superconductors, this temperature is extremely low, close to absolute zero (-273°C).
- **Applications:**
  - **Magnetic Resonance Imaging (MRI):** Superconducting magnets are essential for high-precision imaging in MRI machines.
  - **Maglev Trains:** Superconductors facilitate frictionless, high-speed trains that float above tracks due to the Meissner effect.
  - **Power Grids:** Superconductors are being investigated for efficient power transmission with minimal energy loss over long distances.

OSMOSIS AND REVERSE OSMOSIS

Osmosis

- **Definition:** The **passive movement of water molecules** through a **semipermeable membrane** from an **area of lower solute concentration to higher solute concentration**, aiming to balance concentrations.
- **Mechanism:** Relies on natural osmotic pressure, allowing water to pass while preventing solutes from moving freely.

- **Applications:** Involves water absorption in plants, fluid balance in animal cells, and kidney filtration.

Reverse Osmosis (RO)

- **Definition**: An artificial process that forces water through a semipermeable membrane from an area of high solute concentration to low concentration using external pressure, against the natural flow of osmosis.
  - **Mechanism:** Requires energy to overcome osmotic pressure, blocking solutes and larger particles while allowing only water molecules to pass.
  - **Applications:** Commonly used in desalination of seawater, purification of drinking water, industrial wastewater treatment, and home water purification systems.

WATER FILTRATION TECHNOLOGY

1. **Reverse Osmosis (RO):**
   - **Core Technology:** Forces water through a semipermeable membrane under pressure.
   - **Science:** Effectively filters out salts, heavy metals, and dissolved solids, making it suitable for desalination and household purifiers.
2. **Ultraviolet (UV) Filtration:**
   - **Core Technology:** Uses UV light to disinfect water.
   - **Science:** Disrupts the DNA of bacteria, viruses, and other pathogens, ensuring biologically contaminated water is purified.
3. **Carbon Filters:**
   - **Core Technology:** Utilises activated carbon for adsorption.
   - **Science: Adsorbs** organic compounds, chlorine, and harmful chemicals, enhancing taste and odour, commonly employed in home water filtration systems.
4. **Carbon Nanotube Filtration:**
   - **Core Technology:** Employs carbon nanotubes for advanced filtration.
   - **Science:** Blocks nanoparticles, bacteria, and viruses while allowing water to pass through, still in the experimental stage with promising applications for efficient filtration.
5. **Membrane Bioreactors (MBRs):**
   - **Core Technology:** Combines biological treatment processes with membrane filtration.
   - **Science:** A bioreactor breaks down organic matter, while membranes separate treated water from solids, producing high-quality effluent in wastewater treatment.
6. **Microfiltration and Ultrafiltration:**
   - **Core Technology:** Uses membranes with small pores (0.1 to 0.01 microns).
   - **Science:** Removes suspended particles, bacteria, and some viruses, utilised in water treatment plants and household systems to enhance water quality.
7. **Ion Exchange:**
   - **Core Technology:** Utilises resin beads for ion replacement.
   - **Science:** Replaces unwanted ions (e.g., calcium and magnesium) with sodium or potassium ions, primarily used in water softening systems.
8. **Hydrogel:**
   - **Core Technology:** Composed of three-dimensional polymer networks.
   - **Science:** Retains large amounts of water while capturing heavy metals from industrial wastewater; also used in drug delivery systems and mobile air-conditioning.
9. **Distillation:**
   - **Core Technology:** Involves boiling water and condensing steam back into liquid form.
   - **Science:** Leaves impurities behind, effectively purifying water in laboratories and applications where energy use and mineral removal are crucial.

Oilzapper:

Oil zapper is a microbial product containing oil-degrading bacteria. It is used for bioremediation to clean up oil spills by breaking down hydrocarbons into non-toxic substances, offering an eco-friendly solution for environmental contamination.

POLLUTION CONTROL TECHNOLOGIES

1. **Electrostatic Precipitators (ESP):**
   - **Core Technology:** Uses electrostatic charges to remove particulate matter from exhaust gases.
   - **Science:** Relies on electromagnetism to attract and capture particles.
2. **Baghouse Filters:**
   - **Core Technology:** Employs fabric bags or filters to trap particulate matter.
   - **Science:** Utilises mechanical filtration principles to separate solids from gases.
3. **Scrubbers:**
   - **Core Technology:** Uses liquid sprays or gases to remove harmful gases or particulates.
   - **Science:** Applies chemical absorption principles to neutralise pollutants.
4. **Catalytic Converters:**
   - **Core Technology:** Converts harmful gases (CO, NOx) into less harmful emissions (CO_2, N_2, H_2O) using a catalyst.
   - **Science:** Accelerates chemical reactions without consuming the catalyst.
5. **Flue Gas Desulfurization (FGD):**
   - **Core Technology:** Removes sulphur dioxide (SO_2) from exhaust gases using chemical absorbers like lime or limestone.

- **Science:** Involves acid-base neutralisation reactions.

6. **Biofilters:**
   - **Core Technology:** Uses microorganisms to decompose pollutants, such as Volatile Organic Compounds (VOCs).
   - **Science:** Demonstrates the application of microbiological processes in air treatment.
7. **Cyclone Separators:**
   - **Core Technology:** Separates particles from gases using centrifugal force.
   - **Science:** Utilises fluid dynamics to achieve separation based on density differences.
8. **Activated Carbon Filters:**
   - **Core Technology:** Adsorbs pollutants like VOCs and heavy metals onto activated carbon.
   - **Science:** Utilises adsorption principles involving the chemical affinity of pollutants to carbon surfaces.
9. **Wet Scrubbers:**
   - **Core Technology:** Captures gaseous pollutants by passing them through a liquid medium (water or chemicals).
   - **Science:** It is particularly effective in controlling sulfur dioxide (SO_2), hydrogen chloride (HCl), ammonia (NH_3), and other acid gases, as well as dust particles and volatile organic compounds (VOCs).
10. **Oxidation Ponds and Lagoons:**
    - **Core Technology:** Uses microbial processes to degrade pollutants in wastewater.
    - **Science:** Employs natural biological treatment methods based on microorganism metabolism.
11. **Plasma Arc Technology:**
    - **Core Technology:** Uses high-energy plasma to break down hazardous waste and pollutants.
    - **Science:** Relies on thermal decomposition and ionisation processes to convert waste into less harmful components.
12. **Anaerobic Digesters:**
    - **Core Technology:** Bioreactors that decompose organic waste in the absence of oxygen, producing biogas.
    - **Science:** Utilises anaerobic bacteria for biochemical breakdown of organic materials.
13. **Membrane Filtration:**
    - **Core Technology:** Removes contaminants using microfiltration, ultrafiltration, or reverse osmosis.
    - **Science:** Employs pressure-driven processes to separate particles based on size.
14. **Incineration:**
    - **Core Technology:** Burns hazardous waste at high temperatures to reduce volume and destroy toxins.
    - **Science:** Involves combustion processes that convert waste into ash, gases, and heat.
15. **Photocatalytic Oxidation:**
    - **Core Technology:** Uses UV light and catalysts to degrade air pollutants such as VOCs and odours.
    - **Science:** Facilitates photochemical reactions that break down pollutants into harmless byproducts.

Artificial rain using cloud seeding is a technique used to modify weather by releasing silver iodide (AgI) into the atmosphere to facilitate the formation of ice crystals, enhancing the cloud's ability to generate rain. In the process of cloud-seeding, chemicals like silver iodide, potassium iodide, and dry ice are dispersed into the sky via airplanes and helicopters.

TECHNOLOGY IN TRANSPORTATION

1. **Maglev (Magnetic Levitation):**
   - **Core Technology:** Uses electromagnetic forces for lift and propulsion.
   - **Physics Involved:** Electromagnetism enables trains to float above tracks, minimizing friction, leading to higher speeds and reduced wear on components.
2. **Hyperloop:**
   - **Core Technology:** High-speed transportation in low-pressure tubes with passenger pods using magnetic levitation and air propulsion.
   - **Physics Involved:** Vacuum environment reduces air resistance, and magnetic levitation reduces friction, allowing for extremely high speeds.
3. **Electric Vehicles (EVs):**
   - **Core Technology:** Powered by electric batteries that store and convert chemical energy into electrical energy. (RAS 2013)
   - **Chemistry Involved:** Rechargeable lithium-ion batteries rely on electrochemical reactions to store and release energy efficiently.
4. **Autonomous Vehicles:**
   - **Core Technology:** Utilises advanced sensors, cameras, and artificial intelligence for navigation.
   - **Physics Involved:** LiDAR and RADAR technologies operate based on the principles of light and sound waves to map surroundings and detect obstacles.
5. **Drones:**
   - **Core Technology:** Unmanned aerial vehicles (UAVs) for transportation and delivery.
   - **Physics Involved:** Aerodynamics principles govern flight stability and control; propulsion is achieved through electric motors and propellers.
6. **Smart Traffic Management Systems:**
   - **Core Technology:** Employs real-time data from sensors and GPS for traffic optimization.
   - **Physics Involved:** Data analysis involves statistical mechanics and dynamics to predict and manage traffic flow efficiently.
7. **Connected Vehicle Technology:**
   - **Core Technology:** Vehicles equipped with communication technologies for data exchange.

- **Physics and Chemistry Involved:** Uses radio frequency communication and networking principles to enhance vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2I) interactions.

8. Alternative Powertrain Vehicles:

- Vehicles using propulsion systems other than conventional petrol or diesel internal combustion engines (ICEs), focusing on sustainable transport via electricity, hydrogen, or hybrid systems.
- Objective: Reduce fossil fuel dependency, lower greenhouse gas emissions, enhance energy efficiency, support India's National Electric Mobility Mission Plan (NEMMP) 2020 and National Green Hydrogen Mission.

Examples of Powertrain Vehicles

- **Full Battery Electric Vehicles (BEVs):** Powered solely by electricity in rechargeable battery packs, using electric motors, no ICE, fuel tank, or exhaust. Electric propulsion replaces ICE, aligns with NEMMP 2020, targeting 30% EV penetration by 2030 via FAME India Scheme. Key Features include Zero tailpipe emissions, reducing environmental impact.
- **Hydrogen Fuel Cell Vehicles (FCEVs):** They generate electricity via hydrogen-oxygen electrochemical reaction in fuel cell stack, powering electric motors; emit water vapor, heat. Key Features include Zero-emission, suited for long-range, heavy-duty applications with fast refueling.
- **Fuel Cell Electric Hybrid Vehicles (FCE-HVs):** They iIntegrate hydrogen fuel cells and rechargeable batteries to power electric motors, using regenerative braking (turns kinetic energy into electricity by reversing the process that drives the car forward.) . Key Features include - Combine fuel cell range, battery power for efficiency.

Advancements in Indian Railways

- The National Rail Plan aims to create a 'future ready' railway system by 2030. The objective of the Plan is to create capacity ahead of demand, which in turn would also cater to future growth in demand right up to 2050 and also increase the modal share of Railways to 45% in freight traffic and to continue to sustain it.
- 'Kavach' is an indigenously developed Automatic Train Protection (ATP) system by Indian Railway. The name "Kavach," meaning "shield" in Hindi, reflects its purpose of delivering robust protection and upholding top safety standards in railway operations. For smooth functioning, Radio Frequency Identification (RFID) tags are placed throughout the entire track length to enable the Kavach system to track train positions and detect any potential safety issues along the route.

INTELLECTUAL PROPERTY RIGHTS

Intellectual Property Rights (IPRs) refer to the exclusive rights granted to owners over their **inventions, designs, literary, artistic works, and trade symbols**. These rights allow owners to control the use of their intellectual property for a limited period. Nodal Ministry for IPR is Department for Promotion of Industry and Internal Trade (DPIIT), Ministry of Commerce and Industry.

Categories of Intellectual Property Rights

- **Copyrights:** Protects original literary, artistic, and musical works. In India, the Copyright Act grants exclusive rights to creators.
- **Trademarks:** Distinguishes goods or services using symbols, names, and logos. Governed by the **Trademarks Act of 1999**, which aligns India's trademark laws with international standards.
- **Patents:** Protects inventions, granting exclusive rights for up to 20 years. The **Indian Patents Act, 1970**, amended in 2005, prevents **"evergreening"** of patents and ensures compliance with TRIPS.
- **Industrial Design:** Protects the aesthetic aspects of mass-produced objects. Governed by the **Designs Act** in India.
- **Trade Secrets:** Protects confidential business information. Though India lacks a specific statute, trade secrets are protected under common law.
- **Geographical Indications (GI):** Identifies products from a specific region with a unique reputation, governed by the **Geographical Indications of Goods (Registration and Protection) Act, 1999**.
- **Plant Varieties Protection:** Protects new plant varieties under the **Protection of Plant Varieties and Farmers' Rights Act (PPV&FR), 2001**. It also balances breeders' rights with farmers' rights to save and use seeds.

International Conventions Related to IPR

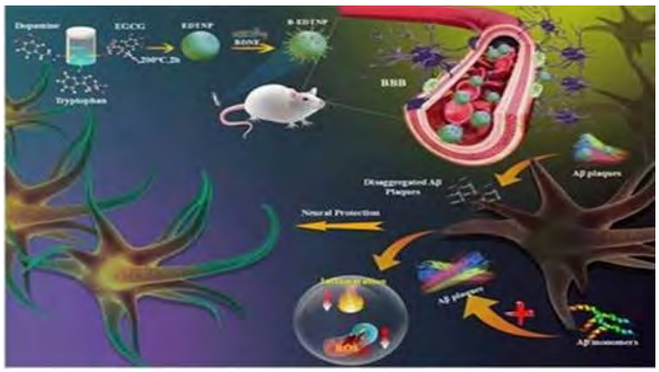
- **TRIPS Agreement:** Administered by WTO, TRIPS sets minimum standards for IPR protection, including GIs, patents, and compulsory licensing.
- **Lisbon Agreement:** Administered by WIPO, this agreement facilitates the international protection of appellations of origin.
- **Berne Convention:** Ensures international **copyright** protection without formalities.
- **Paris Convention:** Provides a framework for the protection of **industrial property**, including inventions and trademarks.
- **WIPO Copyright Treaty (WCT):** Extends copyright protection to the digital environment.
- **Patent Cooperation Treaty (PCT):** Simplifies the international patent filing process by recognizing a single patent application in multiple countries.

RECENT DEVELOPMENTS IN NANOTECHNOLOGY

Institute of Nano Science and Technology (INST): Major Medical Innovations

Alzheimer's Disease: A New Direction of Treatment (EDTNPs Technology)

- **Scientists at the Institute of Nano Science and Technology (INST), Mohali (under DST),** have developed a 'multifunctional nanoplatform' that not only controls the symptoms of Alzheimer's but is also capable of slowing down the disease's progression and aiding in neuronal regeneration.



- **Key Components and Their Role:** This technology is primarily based on **EDTNPs** (EGCG-Dopamine-Tryptophan Nanoparticles):
  - **EGCG (Epigallocatechin-3-gallate):** Obtained from green tea, this antioxidant prevents the aggregation of amyloid protein.
  - **Dopamine:** A neurotransmitter that regulates mood and mental state.
  - **Tryptophan:** An essential amino acid crucial for cognitive functions.
  - **BDNF (Brain-Derived Neurotrophic Factor):** This protein promotes the survival, development, and creation (regeneration) of new neurons.
- **How does this therapy work? (4-in-1 Approach):** While traditional treatments target only a single problem, this nanoparticle technology attacks on four fronts simultaneously:
  - **Clearing Amyloid Beta:** Removing protein clusters that obstruct the nervous system in the brain.
  - **Reduction in Oxidative Stress:** Preventing cellular damage through antioxidant properties.
  - **Preventing Inflammation:** Reducing irritation and swelling occurring in the nerves of the brain.
  - **Neuronal Regeneration:** Revitalizing degenerating nerves and improving memory.

Parkinson's Disease: Targeted Nano-Formulation

- **Innovation:** A specialized nano-carrier has been developed for the continuous and precise delivery of **17- beta-estradiol (hormone)** to the brain.
- **Mechanism:** It protects neurons (nerve cells) from damage.
- **Benefit:** By reducing 'mitochondrial damage', it provides a safe and effective treatment option for Parkinson's patients.

Cancer Treatment: Photothermal Nano-Cups

- **Innovation:** A simple **'single-step method'** has been developed for the fabrication of 'PEGylated' nano-cups.
- **Technology:** These nano-cups absorb **near-infrared light** and convert it into heat.
- **Effect:** Without causing harm to healthy cells, it destroys tumor cells by burning them with heat.

Rheumatoid Arthritis: Smart Drug Delivery System

- **Innovation:** A system based on **'Responsive Microspheres'** for the treatment of joint pain and inflammation (arthritis).
- **Smart Feature:** This system releases medicine only in those joints where inflammation is present.
- **Benefits:** It reduces the side effects of the drug on other parts of the body and provides precise relief from joint pain.

6 Inheritance and variation

GENETICS AND DIVERSITY

Introduction

- That branch of biology in which the **heredity** of traits and **variations** of organisms are studied is called **Genetics**.
  - **The word Genetics was first used by Bateson (1905).** This word is derived from the Greek word **"Gene"**.
- During **sexual reproduction** in organisms, traits are transferred from one generation to another generation. These traits are called **hereditary characteristics**.
  - When these characteristics pass from **parents** to **offspring**, this process is called **Heredity**. **The word Heredity was first used by Spencer (1863).**
- During sexual reproduction, **exchange of genes** takes place, due to which **variations** arise even among organisms of the same species.

Who is Gregor Johann Mendel

- **Gregor Johann Mendel (1822–1884)** is called the **Father of Genetics** because he was the first to clarify the **laws of inheritance**.
- **Mendel was born on 22 July, 1822** in the village of **Heizendorf** in Austria. He received his education in the **Silesion** region.
- **In 1842**, he obtained a degree in **Philosophy** and in **1843** became a priest in a church in the city of **Brunn**.

Mendelism

- In the church garden, **Mendel** conducted **hybridization** experiments on **garden pea (**Pisum sativum**)** for about **7 years (1856–1863)**.
- He presented the results of these experiments in **1865** before the **"Brunn Society of Natural History"**.
  - Later, in **1866**, his research was published under the name **"Experiments on Plant Hybridization"**.
- Based on these experiments, Mendel gave the **laws of inheritance**, which are called **Mendelism. Mendel passed away on 6 January, 188**4.

Mendel's Experiments

Selection of Pea Plant

Mendel chose **Garden pea** for his experiments, because—

(i) It is an **annual plant**, therefore, the study of many generations is possible in a short time.

(ii) Its flowers are **Bisexual**, due to which **Self pollination** occurs easily and a **Pure line / Homozygous** can be obtained.

(iii) **Artificial cross pollination** can also be easily carried out in it by the **Emasculation** method.

(iv) **Clear pairs of contrasting traits** are found in pea plants.

S.No.	Trait	Dominant	Recessive
1.	Height of plant	Tall	Dwarf
2.	Position of flower	Axial	Terminal
3.	Shape of pod	Inflated	Constricted
4.	Color of pod	Green	Yellow
5.	Color of flower	Violet	White
6.	Shape of seed	Round	Wrinkled
7.	Color of seed	Yellow	Green

Characteristics of Mendel's Experiments

(i) Mendel studied only **one trait** at a time.

(ii) He carefully did a **statistical analysis** of the data of his hybridization experiments.

(iii) Mendel also made a well-thought-out **selection of plants** for his experiments.

Rediscovery of Mendelism

- The laws of **Inheritance** given by Mendel remained ignored for about **35 years**.
- After this, in **1900**, three scientists independently rediscovered these laws. These scientists were—
  - **Hugo de Vries** – Holland
  - **Carl Correns** – Germany
  - **Erick von Tschermak** – Austria
- These three scientists, working separately, **rediscovered Mendel's laws** and re-established them in the scientific world.

Mendel's Laws of Inheritance

Based on the experiments conducted on **Garden pea (**Pisum sativum**)**, Mendel gave some important laws, which are called **Laws of Heredity**. These are mainly three-

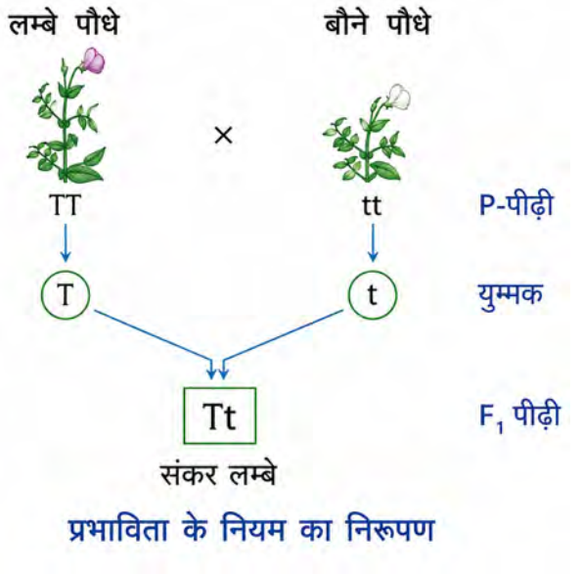
1. **Law of Dominance**
2. **Law of Segregation / Law of Purity of Gametes**
3. **Law of Independent Assortment**

1. Law of Dominance

- **Monohybrid Cross:** This law is based on the results of a **Monohybrid cross**.
- According to this law, when a cross is made between **homozygous plants** with contrasting traits for a single characteristic, the trait that appears in the **F_1 generation** is called **Dominant**.
  - The trait that does not appear in **F_1** is called **Recessive**.

Example

- If a pure **(homozygous)** tall **(TT)** plant is crossed with a pure **(homozygous)** dwarf **(tt)** plant, then all plants **(100%)** of the **F_1 generation** obtained are tall **(Tt)**.

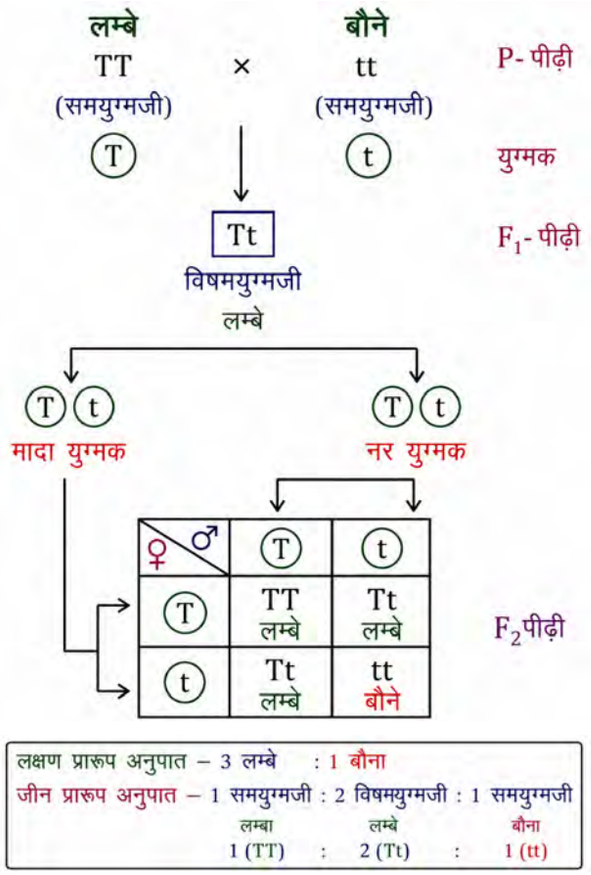


2. Law of Segregation / Law of Purity of Gametes

- **Monohybrid cross:** This law is based on the results of Mendel's **Monohybrid cross**.
- According to this law, when gametes are formed from the **F_1 generation (heterozygous)**, both the **alleles** of a trait **segregate** from each other and enter into different gametes.
- In each gamete, one allele is found for a trait. This is the reason why this law is called the **Law of Segregation, Law of Separation**, and **Law of Purity of Gametes**.
- From this, it is also clear that **alleles do not mix** with each other, but rather segregate independently and pass into the next generation.

Example:

- If a **homozygous tall (TT)** plant is crossed with a **homozygous dwarf (tt)** plant, then all plants **(100%)** obtained in the **F_1 generation** are **heterozygous tall (Tt)**.
- In this **heterozygous (Tt)** condition, both alleles stay together, but they **do not mix** with each other. When gametes are formed, both alleles **segregate from each other** and enter into different gametes.
- For this reason, the trait of **dwarfness (tt)** reappears in the **F_2 generation**.
- **Phenotypic ratio** of **F_2** generation = 3 : 1
- **Genotypic ratio** of **F_2** generation = 1 : 2 : 1



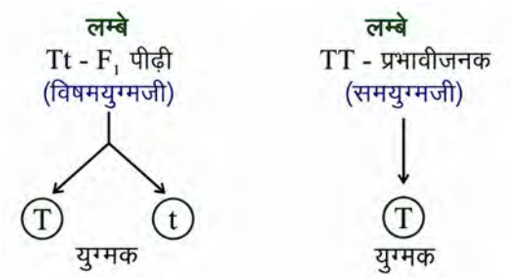
Back Cross

When a plant of the **F_1 generation (Tt)** is crossed with **any one of its parents (TT or tt)**, it is called a **Back Cross**.

Types of Back Cross:

1. Out cross

- In this, the **F_1 generation (Tt)** is crossed with its **dominant parent (TT)**.
- In the offspring obtained from this cross—
  - All plants are **Tall**
  - Out of these, **50\% are Homozygous (TT)**
  - And **50% are Heterozygous (Tt)**



♀ \ ♂	T	t
T	TT लम्बे	Tt लम्बे

लक्षणप्ररूप अनुपात – 100% पौधे लम्बे
जीनप्ररूप अनुपात – 1 : 1
50%TT : 50%Tt
(समयुग्मजी) (विषमयुग्मजी)

2. **Test Cross**

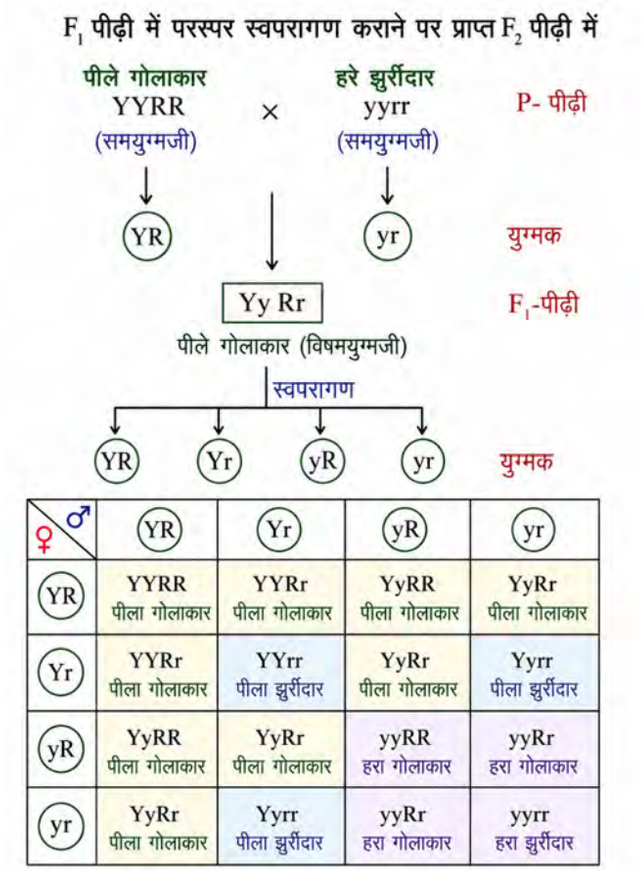
- When the **F_1 generation (Tt)** is crossed with the **recessive parent (tt)**, it is called a **Test cross**.
- In the offspring obtained from this cross—
  - The ratio of **Phenotype** is 1 : 1
  - The ratio of **Genotype** is also 1 : 1
  - **50% plants are Heterozygous tall (Tt)**
  - **50% plants are Homozygous dwarf (tt)**

3. **Law of Independent Assortment**

- **Dihybrid cross:** This law is based on the results of Mendel's **Dihybrid cross**.
- According to this law, when plants with two or more pairs of **contrasting traits** are crossed, the inheritance of one trait has no influence on the inheritance of the other trait.
- That is, the **alleles** of different traits behave **independently** of each other and assort independently during gamete formation.
- For this reason, this law is called the **Law of Independent Assortment**.

Example:

- If a pea plant with **yellow and round (YYRR)** seeds is crossed with a pea plant with **green and wrinkled (yyrr)** seeds, then all plants obtained in the **F_1 generation** have **yellow and round (YyRr)** seeds.
- **Phenotypic ratio** = 9 : 3 : 3 : 1 (Yellow round : Green round : Yellow wrinkled : Green wrinkled)
- **Genotypic ratio** = 1 : 2 : 2 : 4 : 1 : 2 : 1 : 2 : 1 (YYRR : YYRr : YyRR : YyRr : yyRR : yyRr : YYrr : Yyrr : yyrr)



♀ \ ♂	YR	Yr	yR	yr
YR	YYRR पीला गोलाकार	YYRr पीला गोलाकार	YyRR पीला गोलाकार	YyRr पीला गोलाकार
Yr	YYRr पीला गोलाकार	YYrr पीला झुर्रीदार	YyRr पीला गोलाकार	Yyrr पीला झुर्रीदार
yR	YyRR पीला गोलाकार	YyRr पीला गोलाकार	yyRR हरा गोलाकार	yyRr हरा गोलाकार
yr	YyRr पीला गोलाकार	Yyrr पीला झुर्रीदार	yyRr हरा गोलाकार	yyrr हरा झुर्रीदार

Importance of Mendel's Laws of Inheritance

1. Identifying **dominant and recessive traits** in organisms is very important, because some **harmful or lethal genes (Lethal genes)** do not express themselves despite their presence due to being recessive.
2. Mendel's **law of segregation** gives strength to the **gene concept (Gene concept)**.
3. According to this law, **a gene has two alleles (Alleles)**, which control **contrasting traits**.
4. Mendel's laws provide information about **new traits** in new offspring produced by **hybridization (Hybridization)**.
5. Through the hybridization method, **harmful traits** can be removed and **useful traits can be brought together** to develop better varieties.
6. By using Mendel's laws, new varieties of **disease-resistant and high-yielding crops** can be developed.
7. **Eugenics (Eugenics)**, the branch of science related to the improvement of the human race, is also based on Mendel's laws.

Genetics Terminology			
S.No.	**Term**	**Definition**	**Example**
1	Gene	The unit which controls a specific trait (Trait). Mendel called it Factors, later Johannsen named it Gene.	—
2	Allele / Allelomorph	Two contrasting forms of a gene controlling the same trait are called alleles.	T (Tall), t (Dwarf)
3	Homozygous	When both the alleles for a trait are identical, it is called homozygous.	TT, tt
4	Heterozygous	When both the alleles are different, it is called heterozygous.	Tt
5	Phenotype	The external appearance of an organism (External appearance) such as height, color etc., is called phenotype.	Plant appearing tall
6	Genotype	The genetic constitution of an organism (Genetic constitution) is called genotype.	TT, Tt, tt
7	Dominant character	The character which appears in the $\mathbf{F_1}$ generation is called dominant character.	—
8	Recessive character	The character which does not appear in the $\mathbf{F_1}$ generation is called recessive character.	—
9	Monohybrid cross	The cross in which the inheritance of only one trait is studied.	—
10	Dihybrid cross	The cross in which the inheritance of two traits is studied.	—
11	Trihybrid cross	The cross in which the inheritance of three traits is studied.	—
12	Polyhybrid cross	The cross in which the inheritance of several traits is studied.	—
13	Test cross	When the $\mathbf{F_1}$ generation is crossed with the recessive parent.	Tt × tt
14	Back cross	The cross in which the $\mathbf{F_1}$ generation is crossed with any one parent.	Tt × TT / tt
15	Reciprocal cross	Such a cross in which once 'A' is made male and 'B' is made female and the second time 'A' is made female and 'B' is made male to carry out the cross.	
16	Parental generation	Those plants between which the cross is carried out are called parental generation.	P generation
17	$\mathbf{F_1}$ (First filial generation)	The first offspring obtained from the cross of parents is called $\mathbf{F_1}$ generation.	—
18	$\mathbf{F_2}$ (Second filial generation)	The offspring obtained from the cross of $\mathbf{F_1}$ generation is called $\mathbf{F_2}$ generation.	—
19	Monohybrid ratio	The ratio obtained from a monohybrid cross is called monohybrid ratio.	3 : 1
20	Dihybrid ratio	The ratio obtained from a dihybrid cross is called dihybrid ratio.	9 : 3 : 3 : 1

Sex Determination

- Both parents have an equal contribution to the DNA of the offspring formed during reproduction. If both parents play a role in determining the traits of the offspring, then each parent gives one copy of each gene to the offspring. This means that in each plant there are two sets of genes, in which one set is obtained from each parent.
- Genes are not present as a single DNA strand, but they are found in different forms, which we call traits. In each cell, there are two copies of each trait—one received from the father and one from the mother.
- In germ cells (stamen or egg), only one copy of each trait goes. When both these gametes meet each other, the number of chromosomes in the offspring becomes normal again (two copies). Through this process, the stability of the DNA of the offspring is maintained.

Process of Sex Determination

- The methods of sex determination are also different in different organisms. In some cases it depends

on the environment, while in some it is genetically determined.

- For example, in some reptiles, the temperature of egg incubation determines whether the offspring will be male or female. In some animals like snails, sex determination can change, which indicates that sex determination in them is not on a genetic basis.

- But sex determination in humans is completely on a genetic basis. That is, the genes received from the parents determine whether the offspring will be a boy or a girl. Now the question is that when an equal set of genes is received from both parents, then how is sex determined?
- Its answer is hidden in chromosomes. There are a total of 23 pairs of chromosomes in humans, out of which 22 pairs are normal and one pair is responsible for sex determination.
- In females (women), this pair is 'XX', meaning both chromosomes are identical. In males (men), this pair is 'XY', which contains one 'X' and one 'Y' chromosome. The 'Y' chromosome is smaller in size.
- When offspring is formed, it always receives only an 'X' chromosome from its mother. But from the father, it receives either an 'X' or a 'Y' chromosome.
  - If an 'X' chromosome is received from the father, then the offspring will be 'XX' — meaning a girl
  - If a 'Y' chromosome is received from the father, then the offspring will be 'XY' — meaning a boy
- Thus, the sex of the offspring actually depends on the chromosome given by the father.

7 Biotechnology and Genetic Engineering

BIOTECHNOLOGY

It is the application of the principles of engineering and biological science to create new products from raw materials of biological origin, for example, **vaccines** or **food**. The two core fields that enabled the birth of modern biotechnology are:

- **Genetic Engineering:** It includes techniques to alter the chemistry of genetic material (DNA and RNA) to introduce these into host organisms and thus change the traits of the host organism.

BASICS OF GENETICS

Gene

- A gene is a segment of DNA that contains the necessary information to produce a functional product, typically a protein. Genes can vary in size and function, with humans estimated to have about 19,000,-25,000 genes. Genes can be classified into:
  - **Structural Genes:** Code for proteins.
  - **Regulatory Genes:** Control the expression of other genes.
  - **Non-coding Genes:** Do not code for proteins but have regulatory functions.

DNA

- Deoxyribonucleic Acid (DNA) is a molecule that contains the genetic instructions for the development, functioning, growth, and reproduction of all known organisms and many viruses.
- DNA is composed of two long strands that form a double helix, consisting of four nucleotide bases: **Adenine (A), Thymine (T), Cytosine (C) and Guanine (G)**.
- The sequence of these bases encodes genetic information. The specific pairing of the bases (A with T, and C with G) allows for the replication of DNA.

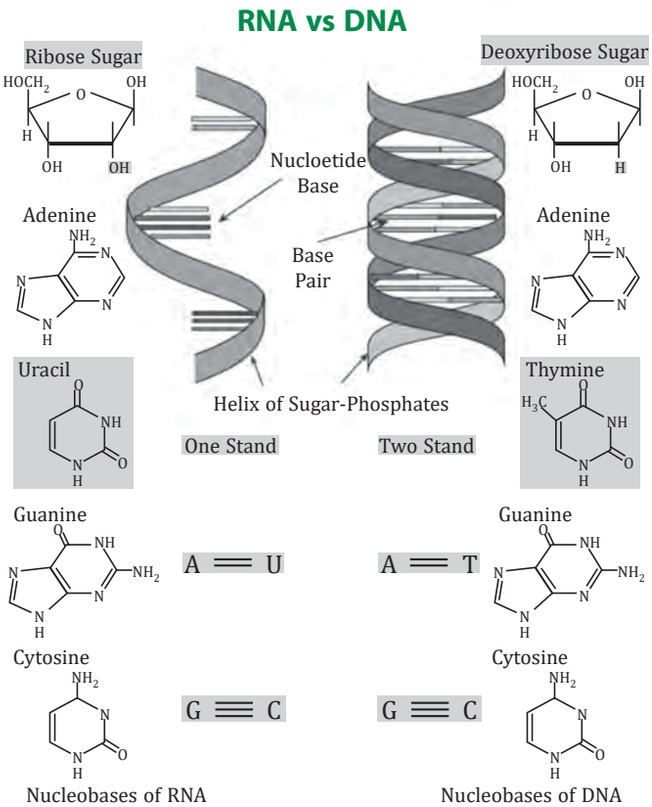
Chromosome

- **Chromosomes** are thread-like structures composed of DNA and proteins, found in the nucleus of most living cells. They carry genetic information in the form of genes, which determine the hereditary traits passed from one generation to the next.
- Each species has a characteristic number of chromosomes in its cells; for example, humans have 46 chromosomes, organized into 23 pairs.

Important Chromosomal Disorders (RAS 2021/2018)

Disorder	Cause	Chromosome Involved
Down's Syndrome	Trisomy (extra copy)	Chromosome 21
Turner's Syndrome	Monosomy (missing X)	XO in females
Klinefelter's Syndrome	Extra X	XXY in males
Cri-du-chat Syndrome	Deletion	Chromosome 5

RNA



- **RNA (Ribonucleic Acid)** is a single-stranded molecule involved in various biological roles, primarily related to the synthesis of proteins and the transmission of genetic information. They are mainly found in nucleus and cytoplasm.
- It is similar to DNA but differs in several key aspects, such as **having ribose sugar instead of deoxyribose** and using the **nitrogenous base uracil (U) instead of thymine (T)**.
- RNA consists of four nitrogenous bases: Adenine(A), Cytosine(C), Uracil(U), and Guanine(G).

Protein Synthesis

- Flow of Genetic Information from DNA to Proteins.
- Central Dogma states that the genetic information flows from DNA to RNA to Protein.

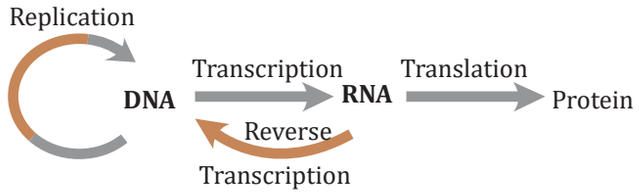


Fig 7.1: Flow of Genetic Information

- **DNA Replication:** DNA replication is the process by which DNA makes a copy of itself during cell division.
- **Transcription:** The process by which a cell makes an RNA copy of a piece of DNA. This RNA copy, called messenger RNA (mRNA), carries the genetic information needed to make proteins in a cell. As mRNA attaches to ribosome to start protein synthesis, tRNA brings amino acids to make a chain of amino acids which ultimately forms the protein.
- **Translation:** The process by which a cell makes proteins using the genetic information carried in messenger RNA (mRNA). The mRNA is made by copying DNA, and the information it carries tells the cell how to link amino acids together to form proteins. Translation takes place in the cytoplasm of a cell on ribosomes.

Dark DNA

- **Dark DNA** refers to genomic regions that are difficult to detect or interpret using standard sequencing methods, often due to high mutation rates or repetitive sequences.
- While traditionally considered **"junk DNA,"** recent research suggests that dark DNA may play roles in gene regulation, evolution, and species adaptation, though its precise functions remain under investigation.

Adenovirus and Retrovirus

Virus Type	Adenovirus	Retrovirus
Genome	DNA	RNA
Envelope	Non-enveloped	Enveloped
Mechanism of Infection	Enters through endocytosis; DNA replicates in the nucleus without integration into the host genome	RNA converted into DNA via reverse transcriptase; integrates into the host genome
Replication Site	Nucleus (no integration)	Integrates into the host genome
Key Enzymes	None (direct DNA replication)	Reverse transcriptase, Integrase
Acute/ Chronic Infection	Acute (short-term infection)	Chronic (long-term infection)
Examples	Human Adenovirus, Adenovirus vectors	HIV, HTLV

GENOME SEQUENCING

- It is the process of determining the complete DNA sequence of an organism's genome. It involves identifying the exact order of the four nucleotide bases (adenine, thymine, cytosine, and guanine) across all chromosomes.
- Genome sequencing provides insights into genetic makeup, allowing researchers to study genes, understand hereditary traits, identify mutations linked to diseases, and drive advancements in personalized medicine and biotechnology.

Human Genome Project

- In the 1980s, scientists began discussing the possibility of sequencing all **3.2 billion nucleotide pairs** in the human genome.
- These discussions led to the launch of the Human Genome Project in 1990. The initial goals of the Human Genome Project were:
  - To map all the human genes,
  - To construct a detailed physical map of the entire human genome, and
  - To determine the nucleotide sequence of all 24 human chromosomes by the year 2005.

Genome India Project

- The Genome India Project, initiated by the **Department of Biotechnology in 2020**, aims to sequence the genomes of 10,000 individuals across India.

- By analyzing this genetic data, the project seeks to understand disease patterns and support predictive diagnostics, personalized medicine, and targeted preventive care.
- Led by the **Centre for Brain Research at IISc, Bengaluru**, and involving 20 institutions, the project advances India's capabilities in next-generation healthcare and precision medicine.

Human Microbiome Initiative of Select Endogamous Population of India

- This project aims to comprehensively characterize human-associated microbes in diverse endogamous groups, including tribal populations with minimal modern lifestyle influence.
- The study examines how diet, lifestyle, geography, and age affect the gut microbiome using metagenomic approaches.

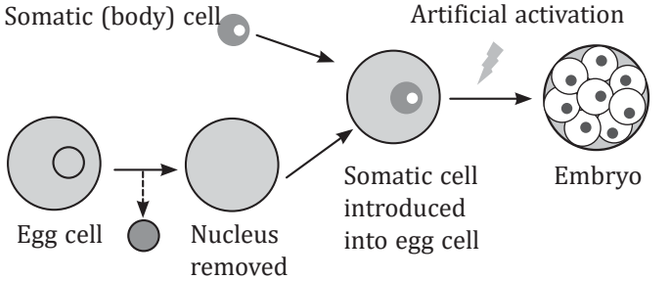
The Rajiv Gandhi Centre for Biotechnology (RGCB), an autonomous biotechnology research institute under DBT, is located in Thiruvananthapuram, Kerala.(RAS 2023)

Earth Bio-Genome Project

- The Earth Bio-Genome Project is a project aiming at analysing and sequencing genomes and building a new basis for biology to drive solutions for biodiversity preservation and human society sustainability.
- The Earth Bio-Genome Project (EBP) is a worldwide group of scientists who plan to sequence, classify, and characterise the genomes of all eukaryotic biodiversity on Earth over the course of ten years.
  - It's a global catalogue of life on the planet.
  - In three phases, it hopes to sequence 1.5 million species.
- The EBP project will assist in the creation of a precise genetic sequence as well as the discovery of evolutionary relationships between the species, orders, and families that will make up the Digital Library of Life.

Transcriptome refers to the complete set of RNA molecules (mRNA and non-coding RNAs like tRNA, rRNA and other ncRNAs) expressed in a cell or tissue at a given time.
Aerial metagenomics typically refers to the study of genetic material (such as DNA or RNA) collected from the air, usually in the form of airborne particles or aerosols.

Somatic Cell Nuclear Transfer



In genetics and developmental biology, somatic cell nuclear transfer (SCNT) is a laboratory strategy for creating a viable embryo from a body cell and an egg cell.

Process of SCNT

- **Extraction of Somatic Cell:** A somatic cell is taken from the organism to be cloned. The cell contains the full DNA of the organism.
- **Enucleation of Egg Cell:** An egg cell is collected from a donor female, and its nucleus (which contains genetic material) is removed, leaving an enucleated egg.
- **Nuclear Transfer:** The nucleus from the somatic cell is then inserted into the enucleated egg. This step allows the egg to have the full DNA of the donor organism.
- **Activation and Development:** The reconstructed egg is stimulated (either electrically or chemically) to begin dividing and developing, just like a fertilized egg. It starts to divide into a blastocyst, a pre-embryonic stage.
- **Embryo Implantation:** The developing embryo is implanted into the uterus of a surrogate mother, where it continues to develop into a full organism.

Applications of SCNT

- **Cloning:** SCNT is most famously used for cloning organisms, such as the cloning of **Dolly the sheep** in 1996. This was the first mammal cloned from an adult somatic cell. (RAS 2016/2013)
- **Therapeutic Cloning:** SCNT can be used to create stem cells for therapeutic purposes. These stem cells are genetically identical to the donor organism, making them useful for studying diseases, drug development, and regenerative medicine.
- **Conservation:** SCNT has been explored as a potential tool for cloning endangered species, helping preserve genetic diversity.

Ethical and Scientific Considerations

While SCNT holds promise in various fields such as medicine and conservation, it raises several ethical concerns, particularly regarding animal welfare and the implications of cloning humans. Additionally, SCNT is often inefficient, with a high rate of failure and abnormal development in the cloned organisms.

The INDIgen Project

- It was launched by the **CSIR**, aims to sequence the whole genomes of thousands of Indian individuals to create a comprehensive database reflecting India's diverse population.
- The project seeks to understand the genetic diversity of India and its impact on health, disease susceptibility, and drug response.
- It also supports the development of personalized medicine, predictive diagnostics, and precision healthcare for the Indian population.

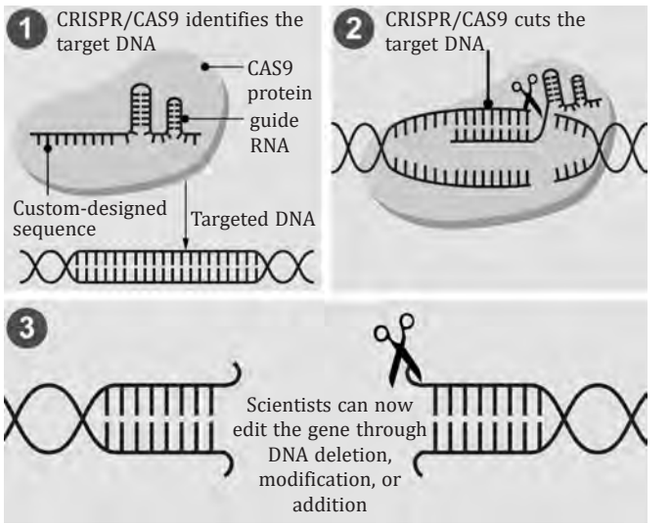
Ganga, India's first cloned cow, born in March 2023, belongs to the Gir breed.

The cloning of Ganga was a significant achievement in biotechnology and animal husbandry, aimed at conserving superior genetic traits and enhancing dairy productivity. The cloning was carried out at the National Dairy Research Institute (NDRI), marking an important milestone in India's livestock research and breeding programs. (RAS 2024)

GENOME EDITING

Genome editing, also known as genome engineering or gene editing, is a sort of genetic engineering that involves inserting, deleting, modifying, or replacing DNA in a living organism's genome.

Genome Editing Techniques



1. **Clustered regularly interspaced short palindromic repeats (CRISPR)- CRISPR- associated protein 9 (Cas9)**: CRISPR is the DNA-targeting component of the system, and it is made up of an RNA molecule, or guide, that is engineered to attach to certain DNA bases via complementary base-pairing. CRISPR-associated protein 9 **(Cas9)** is the nuclease component that cuts the DNA.

   The CRISPR-Cas9 genetic scissors were discovered by Emmanuelle Charpentier and Jennifer A. Doudna, who won the Nobel Prize in Chemistry in 2020.
2. **Transcription activator-like effector nucleases (TALENs)**: Transcription activator-like effector (TALE) domains make up the DNA-binding domain of TALENs.
3. **Zinc-finger nucleases (ZFNs):** ZFNs are fusions between a custom-designed Cys2-His2 zinc-finger protein and the cleavage domain of the FokI restriction endonuclease. FokI cleavage domain, which cuts DNA within a five- to seven-bp spacer sequence that separates two flanking zinc-finger binding sites.
4. **Homing endonucleases or mega-nucleases:** Homing endonucleases, also known as mega-nucleases.
   - These enzymes make extensive sequence-specific contacts with their DNA substrate.
   - However, unlike ZFNs and TALENs, the binding and cleavage domains in homing endonucleases are not modular.

RNA INTERFERENCE (RNAI)

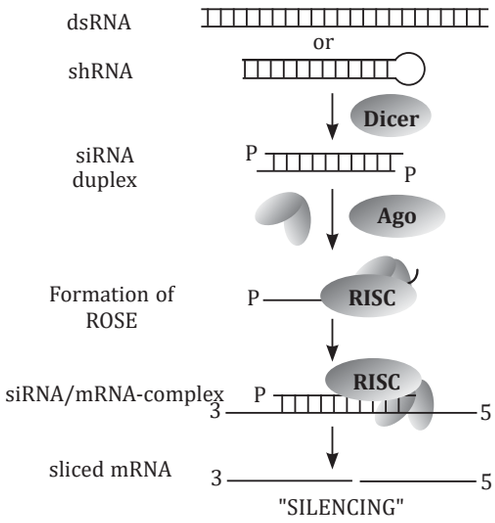
RNA interference (RNAi) is a natural process used by cells to regulate gene expression and defend against viruses. It works by silencing specific genes so that they do not produce proteins.

- **Triggering RNAi:**
  - **The process starts when double-stranded RNA (dsRNA)** enters the cell. This can happen naturally (from a virus) or artificially (scientists can introduce dsRNA to silence specific genes).
- **Dicing the RNA:**
  - An enzyme called Dicer cuts the dsRNA into **small pieces called small interfering RNA (siRNA)**. These are short RNA fragments, about 21-23 nucleotides long.
- **Forming the RISC Complex:**
  - The siRNA pieces are loaded into a protein complex called the **RNA-induced silencing complex (RISC)**. RISC removes one strand of the siRNA, keeping the strand that matches the target mRNA (messenger RNA).
- **Targeting the mRNA:**
  - The siRNA guides RISC to the target mRNA (the molecule that carries the instructions to make a protein). The siRNA binds to the mRNA because they have a matching sequence.
- **Silencing the Gene:**
  - Once bound, RISC cuts the mRNA into pieces, destroying it. Without the mRNA, the cell cannot make the protein encoded by the gene, effectively silencing it.

Applications

- **Research:** Scientists use RNAi to study what specific genes do by turning them off.
- **Medicine:** RNAi-based drugs are being developed to treat diseases like cancer, viral infections, and genetic disorders by silencing harmful genes.

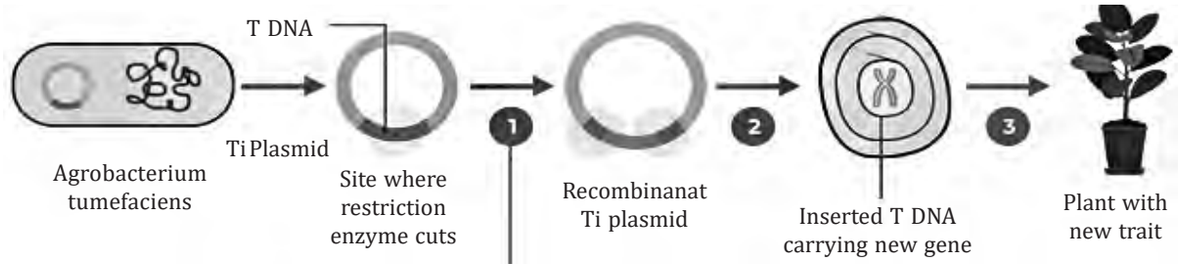
RNAi is like a "**mute button**" for genes, helping cells control which proteins are made.It is used as protection against unwanted invaders like viruses.



Production of Pest-resistant Plants using RNAi

- Several nematodes parasitise a wide variety of plants and animals, including human beings.
- A nematode, **Meloidogyne incognita**, infects the roots of **tobacco plants** and causes a great reduction in yield. A novel strategy was adopted to prevent this infestation which was based on the process of RNA interference (RNAi).
- Using **Agrobacterium vectors**, nematode-specific genes were introduced into the host plant.
- The consequence was that the parasite could not survive in a transgenic host expressing specific interfering RNA.

RECOMBINANT DNA TECHNOLOGY (RAS 2013)



- This technology Combines DNA from different sources to modify genetic makeup.
- **Recombinant DNA:** A DNA molecule made **in vitro with segments from different sources**.

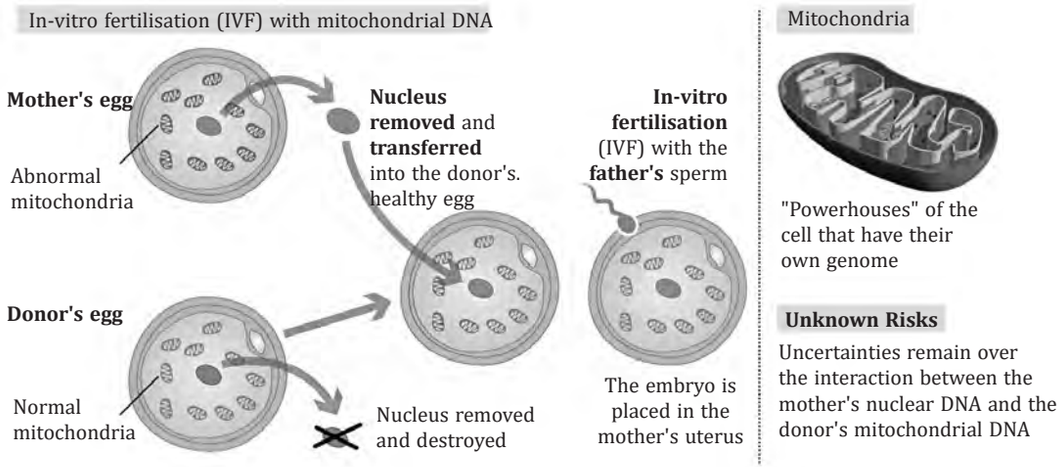
Steps:

- **Restriction Enzymes**:
  - Cut DNA at specific sequences to create fragments.
  - These fragments are combined with DNA from other organisms.
- **Cloning Vectors**:
  - Vectors like plasmids carry recombinant DNA into host cells.
  - Plasmids are small, circular, double-stranded DNA molecules found outside the chromosomal DNA in many bacteria.
  - Key elements in vectors:
    - **Origin of replication**: Ensures DNA replication in the host.
    - **Selectable markers:** Help identify successful recombinants.
    - **Cloning sites:** Allow insertion of foreign DNA.
- **Methods of DNA Insertion**:
  - **Micro-injection**: DNA injected into the nucleus of animal cells.
  - **Biolistics:** DNA-coated metal particles are shot into plant cells.
- **PCR (Polymerase Chain Reaction):** Amplifies the gene of interest to produce many copies.
- **Gene Expression:** Transformed cells express the desired gene and produce useful products (e.g., proteins, enzymes).
- **Applications**:
  - **Medicine:** Production of insulin and vaccines.
  - **Agriculture:** Genetically modified crops.
  - **Research:** Gene therapy, functional genomics.

THREE PARENT BABY/ MITOCHONDRIAL REPLACEMENT THERAPY

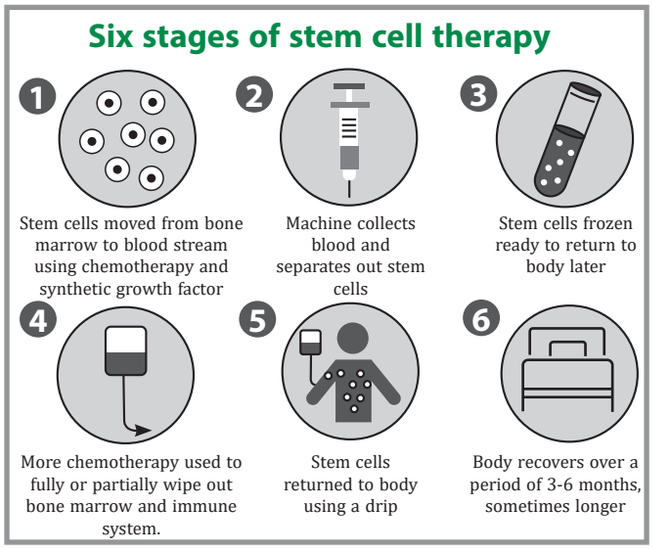
- Involves conceiving a child from IVF (in vitro fertilization) using the genetic material of the parents and the mitochondrial material of a donor.
- Diseased mitochondria are replaced by healthy mitochondria in order to avoid transfer of mitochondrial diseases from the mother to the offspring. Done either before or after IVF of the egg.
- Also known as **Mitochondrial Replacement Therapy (MRT)** and Three-parent babies process. Latter name is used due to involvement of three persons.
- **Mechanism:** Embryo from the biological parents is combined with mitochondria from the donor's egg.

The technique involves using DNA from three people in order to prevent serious inherited diseases


In-vitro fertilisation (IVF) with mitochondrial DNA
Mother's egg
Abnormal mitochondria
Nucleus removed and transferred into the donor's healthy egg
Donor's egg
Normal mitochondria
Nucleus removed and destroyed
In-vitro fertilisation (IVF) with the father's sperm
The embryo is placed in the mother's uterus
Mitochondria
"Powerhouses" of the cell that have their own genome
Unknown Risks
Uncertainties remain over the interaction between the mother's nuclear DNA and the donor's mitochondrial DNA

- **Most common techniques:** Maternal Spindle Transfer (MST) Technique and Pronuclear Transfer (PNT) technique (substitute to MST).
- In both techniques, eggs or embryos are created using nuclear genetic material and healthy donated mitochondria.

STEM CELL THERAPY


Six stages of stem cell therapy
1
Stem cells moved from bone marrow to blood stream using chemotherapy and synthetic growth factor
2
Machine collects blood and separates out stem cells
3
Stem cells frozen ready to return to body later
4
More chemotherapy used to fully or partially wipe out bone marrow and immune system.
5
Stem cells returned to body using a drip
6
Body recovers over a period of 3-6 months, sometimes longer

Stem cell therapy, also known as **regenerative medicine**, promotes the repair response of diseased, dysfunctional or injured tissue using stem cells or their derivatives.

- Researchers grow stem cells in a lab.
- These **stem cells are manipulated to specialise into specific types of cells, such as heart muscle cells, blood cells or nerve cells**.
- The specialised cells can then be implanted into a person.

The Main Sources are:

- Embryonic tissue,
- Fetal tissues, such as fetus, placenta (i.e., amnion and chorion), amniotic fluid and umbilical cord (wharton jelly, blood),
- Specific locations in the adult organism, Example: Fat, bone marrow, skeletal muscle, skin or blood.
- Differentiated somatic cells after they have been genetically reprogrammed.

BIOTECHNOLOGICAL APPLICATION IN AGRICULTURE

- **Genetically Modified (GM) Crops**: GM crops, like **Bt cotton** and **Golden Rice**, are engineered for improved traits. Bt cotton, containing *Bacillus thuringiensis* (Bt) toxin genes, offers resistance to bollworms, reducing pesticide use. **Bollgard I** (single-gene technology) is India's first biotech crop technology (Genetically modified crop) approved for commercialization in India in 2002, followed by **Bollgard II** – (double-gene technology) in mid-2006. (RAS 2013)
  - **Golden Rice** is biofortified with vitamin A to combat malnutrition. (RAS 2013)
  - **Bt Brinjal** is a transgenic brinjal developed by introducing the **cry1Ac gene from the Bacillus thuringiensis** soil bacterium into Brinjal. This brinjal has been genetically modified to withstand insects like the Brinjal Fruit and Shoot Borer (Leucinodes orbonalis).
  - Cytoplasmic male sterility and Gene silencing technique are used to create transgenic crops.
- **Pest and Disease Resistance**: Biotech enables plants to resist pests and diseases. For example, crops

engineered with **Cry proteins** from Bt bacteria protect against pests like cotton bollworms and corn borers.

- **Herbicide Resistance**: Crops like **Roundup Ready soybeans** are modified to withstand herbicides, allowing farmers to control weeds without harming crops.
- **Improved Nutritional Content**: Genetic modifications enhance the nutritional profile of crops, like **biofortified wheat and rice** with higher protein or iron content.
- **Tissue Culture and Micropropagation**: These methods help in the rapid propagation of plants, ensuring uniformity and disease-free planting material.
- **Biofertilizers and Biopesticides**: These eco-friendly options reduce chemical input by using microbial cultures that fix nitrogen or target pests naturally, promoting sustainable agriculture.Some species of Bacteria, Fungi and Flowering plants are employed biopesticides.
- **Food Fortification**

  It is **the practice of adding vitamins and minerals to commonly consumed foods during processing to increase their nutritional value** and is a proven, safe and cost-effective strategy for improving diets and for the prevention and control of micronutrient deficiencies.
  - **Biofortification:** It is the process in which food crops with improved nutritional value are grown, and these projects mainly concentrate on **boosting iron**, **zinc**, **amino acids** and **provitamin A carotenoid** in different food crops.
  - Example: iron biofortification of rice, beans, maize and sweet potato; zinc biofortification of wheat, rice, beans, sweet potato and corn; and Vitamin A biofortification of sweet potatoes, corn and cassava.

Flavr Savr: The First Genetically Modified Food (RAS 2016)

Development and Approval

- **Genetically Modified Tomato:** The Flavr Savr is an explicitly engineered genetically modified tomato.
- **Historical Milestone:** It holds the unique distinction of being the first commercially grown genetically engineered food to be officially granted a license for human consumption.
- **Origin:** The tomato was produced by Calgene, a Californian company, and submitted to the U.S. Food and Drug Administration (FDA) in 1992.

Purpose and Preservation

- **Extended Firmness:** The modification set expectations that the ripe fruit would successfully remain firm for a longer duration.
- **Vine-Ripened Transportation:** This enhanced firmness was specifically intended to allow the fruit to be safely transported to markets after it had completely vine-ripened.

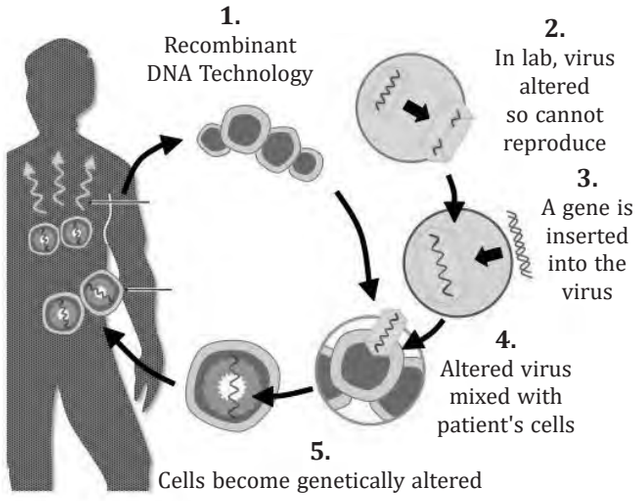
Flavor and Quality Benefits

- **Nutritive Value:** Flavr Savr tomatoes are characterized by possessing a higher nutritive value when compared directly to naturally grown tomatoes.
- **Avoiding Artificial Ripening:** Transporting the fruit post vine-ripening entirely avoids the standard industry practice of harvesting tomatoes while green and artificially ripening them via ethylene treatment.
- **Superior Flavor Profile:** Traditional ethylene treatments merely change a tomato's color to a ripe red without delivering the full, complex array of true vine-ripened tomato flavors that the Flavr Savr successfully preserves.

Regulations of GMs in India

- **EPA,1986:** The Environment Protection Act of 1986 notified the rules governing the management of genetically modified organisms (GMOs) and their products in 1989, with guidelines provided later.
- **GEAC:** The Genetic Engineering Appraisal Committee (GEAC) functions in the **Ministry of Environment, Forest and Climate Change (MoEF&CC)**. As per Rules 1989, it is responsible for the appraisal of activities involving large-scale use of hazardous microorganisms and recombinants in research and industrial production from the environmental angle.

BIOTECHNOLOGICAL APPLICATION IN MEDICINE



- **Recombinant DNA Technology**: Enables the production of essential proteins like **insulin** and **human growth hormone**. Recombinant insulin, produced by inserting the insulin gene into bacteria, is widely used in diabetes management.

- **Gene Therapy**: Used to treat genetic disorders by correcting defective genes. For instance, **Adenosine Deaminase (ADA) Deficiency**, a form of severe combined immunodeficiency **(SCID)**, is treated by introducing functional ADA genes into patients.
- **Vaccines**: Biotechnologically produced vaccines, such as the **Hepatitis B vaccine**, are developed using recombinant DNA techniques, enhancing safety and effectiveness.
- **Monoclonal Antibodies**: These lab-made antibodies target specific cells or proteins, useful in treating diseases like **cancer** and **autoimmune disorders** (e.g., **Rituximab** for lymphoma).
- Monoclonal antibodies are laboratory-produced, identical antibodies created using hybridoma technology or recombinant DNA methods, in which B cells are fused with myeloma cells to target a single antigen epitope with high specificity. They bind antigens through their Fab region to trigger immune responses and are used to treat viral infections such as Nipah virus.
- **Stem Cell Therapy**: Stem cells are used to regenerate damaged tissues. This has applications in treating **spinal cord injuries**, **Parkinson's disease**, and **heart diseases**.
- **Pharmacogenomics**: Studies how genes affect individual responses to drugs, paving the way for **personalized medicine**, which customizes treatments based on a patient's genetic profile.

BIOTECHNOLOGICAL APPLICATION IN ENVIRONMENT

Environmental biotechnology, specifically, refers to the use of procedures to safeguard and restore the environment's quality.

- **Biorock Technology:**

  Biorock is the name given to the substance formed by the electro-accumulation of minerals dissolved in seawater on steel structures that are lowered onto the sea bed and are connected to a power source, e.g., solar panels that float on the surface. It has been used for **Coral restoration.**

Other Techniques	
Bioremediation	Bioremediation is the process of using microorganisms to remove or detoxify toxins from soils, water, or sediments that would otherwise be harmful to human health.
Phytoremediation	Phytoremediation is a bioremediation process that uses various types of plants to remove, transfer, stabilise, and/ or destroy contaminants in the soil and groundwater.
Phyto-degradation	In this process, plants actually metabolize and destroy contaminants with in plant tissues.
Phyto-volatilization	In this process, plants take up water containing organic contaminants and release the contaminants into the air through their leaves.
Biosensors	A biosensor is an analytical device that converts a biological response into a physical, chemical or electrical signal.

DNA BARCODING

- **DNA barcodes** consist of **a standardized short sequence of DNA** (400-800 base pairs) that in principle should be easily generated and characterized for all species on the planet. A massive online digital library of barcodes will serve as a standard to which the DNA barcode sequence of an unidentified sample from the forest, garden, or market can be matched.
- Applications of DNA barcoding **include the identification of new species**, **safety assessment of food**, **identification and assessment of cryptic species**, **detection of alien species**, **identification of endangered and threatened species** etc.

GENE SILENCING/METHYLATION

- Gene silencing is regulation of gene expression to reduce or prevent expression of a gene and can occur via DNA methylation, histone modification and RNA-mediated mechanisms such as RNA interference.
- When genes are silenced, their expression is reduced.
  - Ex: the researchers designed two small RNA molecules that **silence the fungal genes which produce aflatoxin in Groundnut.**

Applications of Gene Silencing

- Specific gene silencing using RNAi in cell culture.
- Cancer treatments
- RNA interference has been used for applications in biotechnology.
- Useful in epigenomic analysis and clinical application of molecular diagnosis.
- Neuro-degenerative disorders treatment.

DNA PROFILING OR DNA FINGERPRINTING (RAS 2018/2013)

- **DNA Profiling** is a forensic technique used to obtain a unique DNA pattern (profile) from an individual or tissue sample. It assists in criminal investigations by comparing suspects' DNA profiles with evidence to determine involvement in crimes. Additionally, it is used for parentage testing, immigration eligibility, and genealogical and medical research.

- **Microsatellite DNA** refers to short, repetitive DNA segments (1-6+ base pairs) that vary among individuals. These non-coding sequences serve as polymorphic markers, valuable for studying inheritance patterns and creating DNA fingerprints in forensic analysis.

GENETIC DISORDERS

- A genetic disorder is a disease that is caused by a change, or mutation, in an individual's DNA sequence.
- The three main categories are:
  - **Single Gene Disorders**: Disorders caused by defects in one particular gene, often with simple and predictable inheritance patterns. Example: **Huntington's disease, Cystic fibrosis.**
  - **Chromosome Disorders**: Disorders resulting from changes in the number or structure of the chromosomes. Example: **Down's syndrome,** which results from an extra chromosome 21.
  - **Multifactorial Disorders** (Complex Diseases): Disorders caused by changes in multiple genes, often in a complex interaction with environmental & lifestyle factors such as diet or cigarette smoke. Example: **Cancer.**

Mutation

- Mutations are changes in the genetic sequence, and they are the main cause of diversity among organisms.
- A single mutation can have a large effect, but in many cases, evolutionary change is based on the accumulation of many mutations with small effects.
- Example: **Sickle cell anaemia** disease in humans caused due to single gene mutation

Sickle Cell Anaemia

Normal red blood cells Sickle cell anemia

- It is an inherited blood disorder in affected individuals at birth, causing the production of abnormal haemoglobin.
- Normally, the haemoglobin protein, which resides inside red blood cells, attaches to oxygen in the lungs and carries it to all parts of the body.
- In **sickle cell disease, the haemoglobin is abnormal, causing the red blood cells to be rigid and shaped like a C or sickle,** the shape from which the disease takes its name.
- Sickle cells can get stuck and block blood flow, causing pain and infections.

Biometric Identification

Fingerprint, Iris scanning, Retinal scanning and Voice recognition are used for biometric identification of person.

RECENT DEVELOPMENTS IN BIOTECHNOLOGY

Bacillus subtilis

- **State Microbe:** Kerala has become the first state in the country to declare **'Bacillus subtilis'** as its 'State Microbe'.
- **Nature:** It is a Gram-positive, rod-shaped bacterium.
- **Type:** It is considered a probiotic (beneficial bacterium).
- **Availability:** It is naturally found in soil, water, and the human gut.
- **Tolerance:** It possesses the ability to form **'endospores'** to survive in adverse conditions (such as high temperatures).

BIRSA-101

- **Launch:** Launched on November 18 by Union Minister Dr. Jitendra Singh.
- This therapy is dedicated to **Bhagwan Birsa Munda**.
- This is India's first indigenous CRISPR-based gene therapy for **Sickle Cell Disease**.
- **Disease Impact:** Sickle Cell Disease particularly affects the tribal population of India.
- **Development:** Developed by CSIR–Institute of Genomics and Integrative Biology (IGIB).
- **Significance:** It will play a crucial role in the mission to make India sickle cell-free by 2047.

Bio-Bitumen via Pyrolysis

- This initiative is being operated under **'Clean, Green Highways'**.
- **Program:** A technology transfer program for Bio-Bitumen via Pyrolysis was organized in New Delhi, which is an indigenous innovation of CSIR-CRRI and CSIR-IIP.
- **Technology:** Bio-bitumen is produced from agricultural residue (paddy straw) through Bio-Bitumen via Pyrolysis for road construction.
- **Field Trial:** A 100-meter trial patch was prepared on the Jorabat–Shillong Expressway (NH-40) in Meghalaya.
- **Special Achievement:** CSIR is the first institute globally to scale up bio-bitumen to an industrial/ commercial level within a single year.

8 Human Health Care

According to the WHO, "Health is a state of complete physical, mental, and social well-being and not merely the absence of disease or infirmity." Health encompasses various dimensions, including physical, mental, social, emotional, and spiritual well-being.

BASIC CONCEPTS

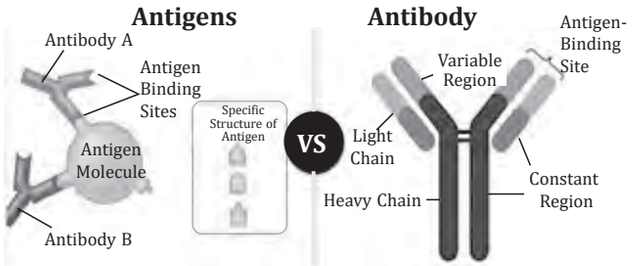
Pathogens

Pathogens are microorganisms causing diseases in plants and animals. Most are parasites that harm their hosts. The main categories include:

1. **Bacteria:**
   - Prokaryotic microorganisms that can produce toxins and elicit strong immune responses.
   - **Example:** Streptococcus bacteria can cause strep throat.
2. **Viruses:**
   - Obligate intracellular parasites that can only replicate inside a host cell.
   - **Example:** The influenza virus leads to seasonal flu outbreaks.
3. **Protozoans:**
   - Unicellular eukaryotes, often free-living or parasitic.
   - **Example:** Plasmodium, which causes malaria, is transmitted by mosquitoes.
4. **Helminths:**
   - Multicellular parasitic worms visible to the naked eye, living in hosts' bodies.
   - **Example:** Tapeworms inhabit the gastrointestinal tract.
5. **Fungi:**
   - Eukaryotic organisms that absorb organic matter from their environment.
   - **Example:** Candida species can cause opportunistic infections.

Antigen and Antibody

Antigens trigger immune responses, while antibodies neutralise pathogens, forming the basis of adaptive immunity.



Feature	Antigen	Antibody
Also Called	Immunogens	Immunoglobulins
Molecular Type	Lipids, proteins, carbohydrates, nucleic acids	Proteins
Effect	Cause allergic reactions and illnesses	Protect against antigens
Specific Binding Site	Epitopes (regions on antigens)	Paratopes (variable regions on antibodies)
Origins	Originates outside the body	Originates within the body

IMMUNITY AND VACCINES

Immunity

Immunity is the body's defence mechanism against infections caused by foreign antigens from bacteria, viruses, fungi, toxins, and foreign substances. It can be categorised into several types:

1. **Humoral Immunity:**
   - Activated by B lymphocytes, which produce antibodies to neutralise pathogens and their toxins. These antibodies complement proteins that target specific diseases.
2. **Cellular Immunity:**
   - Involves T lymphocytes that directly attack infected cells and help regulate the immune response through cytokines.
3. **Types of Immunity:**
   - **Innate Immunity:**
     - The first line of defence, including physical barriers (skin, mucus) and reflexes (cough).
   - **Acquired Immunity:**
     - Developed through exposure to infectious agents or vaccines, providing long-term protection.
     - Immunity can be acquired either actively or passively; thus enabling active and passive immunity respectively.
     - **Active Immunity:** It develops when the immune system produces its own antibodies in response to exposure to an antigen. It is usually

longer lasting compared to passive immunity. Based on how it is acquired it cab be further classified into:

- **Natural Active Immunity:** Acquired through natural exposure to a pathogen (ex- recovering from an infection like chickenpox).
- **Artificial Active Immunity:** Acquired through vaccination, where a weakened or inactivated pathogen, or a part of it, is introduced to stimulate the immune system. ex- COVID vaccine.
- **Passive Immunity:** Temporary immunity gained through the transfer of antibodies from another individual, such as maternal antibodies to a foetus or antiserum for short-term protection against diseases like hepatitis.

  Example: Covid Plasma Therapy

- **Herd Immunity:**
  - When a significant portion of a population is immune, reducing the spread of infectious diseases.
- **Immunoglobulins:**
  - Antibodies produced in response to antigens, classified into five major types (IgG, IgM, IgA, IgD, IgE), providing protection against pathogens.

4. **Immunotherapy:**
   - A treatment method that enhances the immune system to fight diseases, particularly cancer.
5. **Monoclonal Antibodies:**
   - Artificially generated antibodies targeting specific antigens to assist the immune response.

Vaccines

Vaccines are biological preparations that contain weakened, killed, or fragmentary microorganisms or their toxins. They are primarily used to prevent diseases and can be administered through various methods, including injections, oral, or nasal routes.

Types of Vaccines

1. **Weakened (Attenuated) Vaccines:**
   - Composed of live microorganisms that have been modified to reduce their virulence. Examples include vaccines for measles, mumps, rubella, and oral polio- OPV **(Sabin vaccine)**. (RAS 2016)
2. **Inactivated Vaccines:**
   - Contains killed or inactivated organisms. These vaccines often require higher doses for an effective immune response. Examples include vaccines for rabies and injectable polio- IPV **(Salk vaccine)**.
   - **Exmaple:** HPV, Hepatitis B
3. **Subunit Vaccines:**
   - Made from specific proteins of the infectious agents, including toxoids inactivated to stimulate immunity. Examples include vaccines for **tetanus and diphtheria.**
4. **Recombinant DNA Technology Vaccines:**
   - Use genetic material from pathogens to induce an immune response without causing disease. For Example: **Hepatitis B vaccine, Human Papillomavirus (HPV).**
5. **Conjugate Vaccines:**
   - Conjugate vaccines enhance immune responses by **linking weak antigens, such as bacterial polysaccharides, to strong protein antigens.** This combination helps stimulate a robust immune response, including activation of T-helper cells, making them especially effective in young children, whose immune systems may not respond well to polysaccharides alone.
   - These vaccines are critical for preventing infections caused by encapsulated bacteria, such as **Haemophilus influenzae type b (Hib), Streptococcus pneumoniae (in Pneumococcal Conjugate Vaccine)**, and **Neisseria meningitidis** (in Meningococcal Conjugate Vaccine). They provide long-lasting protection and have significantly reduced the burden of diseases like pneumonia and meningitis.
6. **Messenger RNA (mRNA) Vaccines:**
   - Deliver mRNA that instructs cells to produce antigens, triggering an immune response. An example is **GEMCOVAC-19,** India's first indigenous mRNA vaccine for COVID-19.

Mission Indradhanush

Launched in 2014 by the Government of India, **Mission Indradhanush** aims to enhance vaccination coverage for children and pregnant women, particularly in underserved areas. The program targets ten diseases, including:

- Tuberculosis,
- Polio
- Hepatitis B
- Diphtheria
- Pertussis
- Haemophilus Influenzae type b
- Japanese Encephalitis (sub national) and
- Pneumococcal Pneumonia (sub national).
- Tetanus
- Measles
- Rubella
- Rota virus

COMMUNICABLE DISEASES

- Infectious diseases are a leading cause of death in children and young adults worldwide. Lower respiratory infections, diarrhoeal diseases, and tuberculosis are among the most common and deadliest types of infectious diseases.
- Based on the causative agents, these diseases can be classified as:
  - Bacterial
  - Viral
  - Parasitic
  - Fungal

Bacterial Diseases

❖ Bacteria are unicellular organisms that reproduce sexually or asexually and can exist in an environment with oxygen (aerobic) or in a situation lacking oxygen (anaerobic). Some may enter a dormant state and form spores where they are protected from the environment and may remain viable for years.

Table 8.1: Bacterial Diseases

Disease	Agent	Vector/Transmission	Treatment/Prevention
Tuberculosis	Mycobacterium tuberculosis (**usually attacks lungs but can affect any part of body**)	Air-Borne	Prevention: Bacille Calmette-Guérin (BCG) Vaccine
Diphtheria (RAS 2023)	Corynebacterium diphtheriae	Person to person- usually through respiratory droplets	Diphtheria, tetanus, and pertussis (DTaP/DTP) vaccine
Cholera (RAS 2013)	Vibrio cholerae	Contaminated water or food	Dukoral Vaccine and Adequate Sanitation
Leprosy (Hansen's Disease)	Mycobacterium leprae	Droplets (from nose and mouth)	Multidrug therapy (MDT)
Whooping cough (Pertussis)	Bordetella pertussis	Air-borne	Diphtheria, tetanus, and pertussis (DTaP/DTP) vaccine
Tetanus	Clostridium tetani	Through spores in environment	Diphtheria, tetanus, and pertussis (DTaP/DTP) vaccine
Plague (RAS 2023/2021)	Yersinia pestis	Flea bites, Direct Contact, Infectious Droplets	Sanitaion and rodent control
Gonorrhea	Neisseria gonorrhoeae	Sexually transmitted disease (STD)	Intramuscular ceftriaxone
Syphilis	Treponema pallidum	Sexually transmitted disease (STD)	Benzathine penicillin G
Typhoid (Enteric Fever) (RAS 2013)	Salmonella typhi	Contaminated drinking water and food	Oral Vaccine, Injectable Vaccine
Pneumococcal Disease (RAS 2023/2013)	Streptococcus pneumoniae	Direct Contact- Respiratory Secretions	Pneumococcal Conjugate Vaccines (PCV13, PCV15, and PCV20)
Streptococcal Pharyngitis	Streptococcus pyogenes	Direct contact, respiratory droplets	Penicillin, amoxicillin
Bacterial Meningitis	Various (e.g., *Neisseria meningitidis*, *Streptococcus pneumoniae*)	Respiratory droplets, direct contact	Antibiotics (e.g., ceftriaxone)
Leptospirosis	Leptospira spp.	Contact with contaminated water	Antibiotics (e.g., doxycycline)
Anthrax	Bacillus anthracis	Inhalation, ingestion, or skin contact	Antibiotics (e.g., ciprofloxacin)
Brucellosis	Brucella spp.	Ingestion of unpasteurized dairy, contact with infected animals	Antibiotics (e.g., doxycycline + rifampin)

Viral Diseases

- A virus is a **nucleic acid molecule (RNA or DNA)** encapsulated in a protein coat or capsid. The virus is not a complete cell and can only replicate inside a living cell (bacteria, plants, fungi etc.). The capsid may have a protective lipid-containing envelope.
- The capsid and envelope facilitate attachment and penetration into host cells (e.g., **via attachment to receptors like ACE 2)** and often contain virulence factors. Inside the host cell, the nucleic acid molecule utilises cellular proteins and processes for virus replication.
- Virus can infect hosts such as Bacteria, Fungi, plants apart from human beings and animals.
- Based on the type of nucleic acids, viruses can be classified as:
  - **DNA viruses** (e.g., Adenovirus) contain usually double-stranded DNA (dsDNA) and rarely single-stranded DNA (ssDNA). These viruses replicate using DNA-dependent DNA polymerase.
  - **RNA viruses** have typically ssRNA (single-stranded RNA) but may also contain dsRNA.
  - **Retrovirus** [e.g., Human Immunodeficiency Virus (HIV)] core contains several copies of reverse transcriptase bound to two identical single-stranded RNA molecules.

The key difference between RNA Viruses and retroviruses is that RNA viruses are viruses that have single-stranded or double-stranded RNA as their genetic material, while retroviruses are viruses that have single-stranded RNA as their genetic material but use DNA intermediates in their life cycle.

Table 8.2: Viral Diseases

Disease	Agent	Vector/Transmission	Treatment/Prevention
Dengue (RAS 2024/2023)	Dengue virus (RNA Virus)	Aedes aegypti or Aedes albopictus female mosquitoes	(Not Approved in India yet.)
Chikungunya (RAS 2024)	Chikungunya virus (RNA Virus)	Aedes aegypti or Aedes albopictus female mosquitoes	(Not Approved in India yet.)
Poliomyelitis (Polio)	Polio virus (RNA Virus)	❖ Person to person: faecal-oral route. ❖ Contaminated water/ food.	❖ Inactivated poliovirus vaccine (IPV) ❖ Oral poliovirus vaccine (OPV)
AIDS	Human Immunodeficiency Virus (HIV) (RNA Virus)	Exchange of body fluids **(excluding saliva)**	Anti Retroviral Therapy (ART) with: ❖ Fostemsavir ❖ Ibalizumab-uiyk ❖ Lenacapavir ❖ Lamivudine ❖ Cabotegravir ❖ Zidovudine etc.
Hepatitis- A, B, C, D, E, G (RAS 2013)	Hepatitis- A, B, C, D, E, G Viruses [All are RNA viruses **except Hepatitis B- a DNA virus**]	❖ Hepatitis A and E- contaminated food or water ❖ Hepatitis B, C, D, G- Parenteral contact with body fluids/blood	❖ HAV Vaccine ❖ HBV Vaccine- also for Hepatitis D ❖ **No Vaccines- Hepatitis C, G**
Chickenpox	Varicella-Zoster Virus	Air-borne Direct Contact	Varivax, ProQuad (MMRV)

Ebola	❖ Zaire ebolavirus (**deadliest strain**) ❖ Sudan ebolavirus ❖ Taï Forest ebolavirus ❖ Bundibugyo ebolavirus ❖ **All are RNA Viruses**	Zoonosis & Body fluids	❖ Ervebo ❖ Zabdeno+Mvabea
Nipah	Nipah virus (NiV) (RNA Virus)	Zoonosis, Direct contact and Food contaminated by body fluid of infected animals	No approved Vaccines
COVID-19	SARS-CoV-2 (many strains) (RNA Virus)	❖ Contact and droplet transmission ❖ Air-borne ❖ **Fomite transmission**	Covaxin, Covishield, Sputnik-V, **GEMCOVAC-OM** (**mRNA vaccine**)
Japanese Encephalitis (RAS 2023)	Japanese encephalitis virus [RNA Virus]	Culex tritaeniorhynchus mosquitoes	Inactivated Vero cell culture-derived Vaccine (IXIARO)
Zika Fever	Zika Virus (RNA Virus)	Aedes aegypti or Aedes albopictus female mosquitoes	No approved Vaccines
Influenza	Influenza virus	Airborne droplets, direct contact	Antiviral medications (e.g., oseltamivir), supportive care
Measles	Measles virus	Airborne droplets	Supportive care, vitamin A
Mumps (RAS 2013)	Mumps virus	Airborne droplets, direct contact	Supportive care
Rubella	Rubella virus	Airborne droplets	Supportive care
Herpes Simplex	Herpes simplex virus	Direct contact (oral and genital)	Antivirals (e.g., acyclovir)
Rabies (RAS 2021)	Rabies virus	Animal bites (usually from bats or dogs)	Post-exposure prophylaxis, supportive care

Smallpox

Smallpox is an acute contagious disease caused by the variola virus, a member of the orthopoxvirus family. Smallpox has been **eradicated in India.** The smallpox vaccine, created by **Edward Jenner in 1796**, was the first successful vaccine to be developed.

Parasitic Diseases

- These are diseases caused by **protozoa**, **helminths**, and **arthropods** (**live within**, **on**, or **at the expense of a host**).
- Protozoa include unicellular organisms, such as the flagellates- **Giardia** and **Trichomonas**, and **amoebae-Entamoeba** (causing **enteric** and **gynaecological disorders**).
- Helminths are worms that infest humans. Arthropods include **lice**, **fleas**, **sandflies**, **blackflies**, and **ticks**, and **they serve as important disease vectors**.

Table 8.3: Parasitic Diseases

Disease	Agent	Vector/Transmission	Treatment/Prevention
Sleeping Sickness (Trypanosomiasis)	Trypanosoma brucei	Tsetse fly	Pentamidine
Chagas Disease	Trypanosoma cruzi	Triatomine bugs	No Vaccine
Ascariasis	Ascaris lumbricoides (roundworm)	Soil-Transmitted Helminths (STH) [Worm Eggs- Faecal Route]	Albendazole and Mebendazole
Elephantiasis (Lymphatic filariasis) (RAS 2024)	Wuchereria bancrofti, Brugia malayi, Brugia timori	Mosquitoes (various)	Diethylcarbamazine (DEC)
Kala-azar (Leishmaniasis)	Leishmania species (protozoans)	Phlebotomine Sand flies	Miltefosine
Malaria (RAS 2024/2023/2021/2013)	❖ Plasmodium parasites- P. falciparum, P. vivax, P. malariae, P. ovale and P. knowlesi. **P. falciparum** is the **deadliest malaria parasite (common in Africa)** ❖ **P. vivax** is dominant- **outside sub-saharan Africa.**	Female Anopheles mosquitoes	R21/Matrix-M and RTS, S against **P. Falciparum** (**not for other strains**)
Primary Amebic Meningoencephalitis (PAM)	Naegleria fowleri	Water containing Naegleria fowleri enters the nose (not by drinking)	Combination of Drugs
River Blindness (Onchocerciasis)	Onchocerca volvulus	Blackflies (Simulium)	Ivermectin
Giardiasis	Giardia lamblia	Fecal-oral route, contaminated water	Antiparasitic (e.g., metronidazole)
Loa loa filariasis	Loa loa	Deerfly bites	Antiparasitic (e.g., ivermectin)
Ascariasis	Ascaris lumbricoides	Fecal-oral route	Antiparasitic (e.g., albendazole)

Vector Borne Disease

❖ Vector-borne diseases are transmitted by organisms that carry infectious pathogens, significantly impacting global health. These diseases are prevalent in tropical and subtropical regions, often affecting impoverished populations. Environmental factors, such as climate change, can increase vector proliferation.

Vectors	Diseases	Causative Organisms
Mosquitoes	Chikungunya, Dengue, Malaria	Chikungunya Virus, Dengue Virus, Plasmodium
Tse-tse Flies	African Trypanosomiasis	Trypanosoma Brucei
Ticks	Lyme Disease, Tick-borne Encephalitis	Borrelia Burgdorferi, Tick-borne Encephalitis Virus

Wolbachia Method: Wolbachia are safe, naturally occurring bacteria, which have evolved to live inside the cells of many insect species. The World Mosquito Program (WMP) discovered that Wolbachia blocks viruses like dengue, chikungunya and Zika from growing in the bodies of Aedes aegypti mosquitoes. This means that if Wolbachia is established in a mosquito population, it results in decreasing incidence of dengue, Zika, and chikungunya.

Cornavirus (COVID-19)

- COVID-19, caused by the SARS-CoV-2 virus, is a respiratory viral disease. The name "Corona" refers to the crown-like spikes on the virus's surface. Other examples of coronaviruses include SARS, the common cold, and MERS.
- COVID-19 was a new strain of this virus called SARS Cov-2. **Angiotensin Converting Enzyme 2 (ACE2)** has been discovered to be the SARS-CoV-2 virus's receptor. The coronavirus can enter a variety of human cells through this particular protein and spread infection.

Testing Methods for COVID-19

1. **RT-PCR (Reverse Transcription Polymerase Chain Reaction):**
   - A molecular technique used to detect viral RNA in samples. It involves reverse transcription to convert RNA into complementary DNA (cDNA) followed by amplification using polymerase chain reaction (PCR).
   - **Technology Aspect:** High sensitivity and specificity make it the gold standard for diagnosing COVID-19.
2. **RT-LAMP (Reverse Transcription Loop-Mediated Isothermal Amplification):**
   - A rapid method for nucleic acid amplification that operates at a constant temperature, eliminating the need for thermal cycling.
   - **Technology Aspect:** Faster and simpler than RT-PCR, enabling quicker results, which is crucial during outbreaks.
3. **TMA (Transcription Mediated Amplification):**
   - This technique amplifies RNA using enzymes, providing a sensitive and rapid diagnostic tool for detecting viral infections.
   - **Technology Aspect:** TMA offers high sensitivity and specificity with a shorter time-to-result compared to traditional methods.

COVID Vaccines in India

1. **COVAXIN:**
   - An inactivated virus vaccine, which uses killed virus particles to elicit an immune response.
   - **Biological Aspect:** Triggers the body's immune response without causing disease.
2. **Covishield:**
   - A viral vector vaccine using a modified adenovirus to deliver the spike protein of SARS-CoV-2.
   - **Biological Aspect**: The immune system recognizes the spike protein and mounts a response, preparing the body for future infection.
3. **ZyCoV-D:**
   - The first DNA plasmid vaccine in India, which introduces a small, circular piece of DNA that codes for the spike protein.
   - **Biological Aspect**: This DNA is taken up by cells, leading to the production of the spike protein and triggering an immune response.
4. **Sputnik V:**
   - Another viral vector vaccine that uses two different adenoviruses for its two doses, enhancing immune response.
   - **Biological Aspect**: By using two distinct vectors, it minimizes the risk of pre-existing immunity against the vector reducing efficacy.
5. **Biological E's COVID-19 Vaccine (Corbevax):**
   - Protein Sub-unit COVID 19 Vaccine.
   - **Covovax:** SARS-CoV-2 rS Protein (COVID-19) Nanoparticle Vaccine developed by Serum Institute of India, based on the Novavax vaccine technology.

Fungal Diseases

- **Mycoses:** Infections caused by molds and yeasts (types of fungi).
- **Common Fungal Infections:**
  - **Mucormycosis (Black Fungus): (RAS 2021)**
    - Caused by molds from the Mucorales order.
    - Affects sinuses, brain, and lungs, primarily in immunocompromised individuals.
  - **Pneumocystis Pneumonia (PCP):**
    - Caused by *Pneumocystis jirovecii*.
    - Affects the lungs, common in HIV/AIDS patients.
  - **Aspergillosis:**
    - Caused by *Aspergillus* species.
    - Primarily impacts the lungs and respiratory system.
  - **Dermatophytic Infections (Tinea):**
    - Caused by fungi invading hair, skin, or nails.
    - Common across various living organisms.
- **Fungal Infections in HIV:**
  - Major contributors include Cryptococcus, Candida, Aspergillus, and Mucor, causing significant morbidity.

NON-COMMUNICABLE DISEASES (NCD)

The **World Health Organization (WHO)** identifies four major types of non-communicable diseases:

1. Cancer
2. **Cardiovascular Diseases (CVDs)** (e.g., heart attack, stroke)

3. **Chronic Respiratory Diseases (CRDs)** (e.g., asthma, Chronic Obstructive Pulmonary Disease - COPD)
4. Diabetes Mellitus

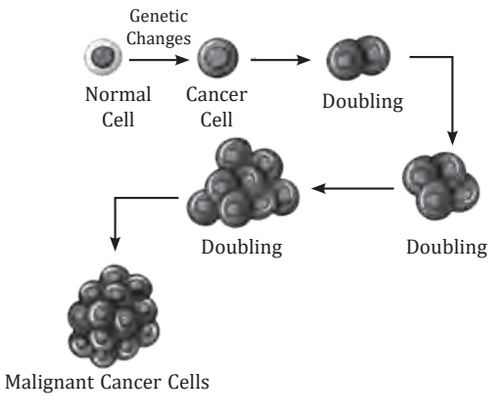
Epidemiology

- **77%** of NCD deaths occur in low- and middle-income countries.
- **CVDs** account for the highest proportion of NCD deaths, followed by cancers, chronic respiratory diseases, and diabetes.
- **Risk Factors:** Major contributors to NCD mortality include tobacco use, physical inactivity, harmful alcohol consumption, unhealthy diets, and air pollution.

Cancer

- **Cancer** occurs when cells divide uncontrollably, forming **tumors**. Tumors can be:
  - **Benign:** Non-cancerous, localized, and do not spread.
  - **Malignant:** Cancerous and can invade surrounding tissues or metastasize (spread) to other parts of the body.

Cancer Development Process



Common Cancers in India

- **Cervical Cancer:** Originates in the cervix and progresses slowly, causing about **75,000 deaths/year** in India. The **Human Papillomavirus (HPV)** vaccine is an effective preventive tool. An immunization campaign targeting HPV is planned in India.
- **Breast Cancer:** Prevalent among women, characterized by the uncontrolled growth of breast cells.
- **Oral Cancer:** Affects both men and women, often linked to tobacco use and poor oral hygiene.

Causes of Cancer: Transformation of normal cells into cancerous neoplastic cells is induced by agents called **carcinogens**, which can be:

- **Physical Carcinogens:** UV and ionizing radiation.
- **Chemical Carcinogens:** Asbestos, tobacco smoke components, alcohol.
- **Biological Carcinogens:** Oncogenic viruses (e.g., HPV, hepatitis B), bacteria, and parasites.

Cardiovascular Diseases (CVDs)

- **CVDs** encompass a range of conditions affecting the heart and blood vessels, causing damage to arteries in organs such as the brain, heart, kidneys, and eyes.

Common Types of CVDs

- **Heart Attack (Myocardial Infarction):** Occurs when the blood supply to the heart is obstructed, **typically by fatty deposits (atherosclerosis)** in the coronary arteries.
- **Stroke:** A condition where blood supply to the brain is interrupted or a blood vessel in the brain bursts. This deprives brain tissue of oxygen and can cause permanent damage.
- **Types of Stroke**
  - **Ischemic Stroke:** Caused by blood clots blocking blood vessels in the brain.
  - **Hemorrhagic Stroke:** Occurs when a blood vessel leaks or ruptures, increasing pressure on brain cells.

Risk Factors: High blood pressure, high cholesterol, diabetes, and a family history of CVDs contribute significantly. Stroke is the second leading cause of death worldwide and the third leading cause of disability.

Chronic Respiratory Diseases (CRDs)

- **CRDs** affect the airways and lung structures. Common CRDs include:
  - **Chronic Obstructive Pulmonary Disease (COPD):** Characterized by persistent respiratory symptoms and airflow limitation.
  - **Asthma:** A chronic inflammatory disease of the airways, causing wheezing, breathlessness, and chest tightness.

Management: Although CRDs are incurable, treatments (e.g., bronchodilators, steroids) help alleviate symptoms and improve quality of life.

Risk Factors: Tobacco smoke, air pollution, occupational chemicals, and childhood respiratory infections contribute to CRDs.

Diabetes Mellitus

Diabetes is a chronic condition arising from insufficient insulin production or ineffective use of insulin by the body, leading to elevated blood glucose levels.

Types of Diabetes

1. **Type 1 Diabetes (T1DM):** The pancreas produces little to no insulin, necessitating daily insulin administration. Causes include genetic predisposition and environmental factors.
2. **Type 2 Diabetes (T2DM):** The most prevalent form; characterized by insulin resistance and/or inadequate insulin production. Often preventable through lifestyle modifications.

NEGLECTED TROPICAL DISEASES (NTDs)

- **NTDs** encompass a diverse group of communicable diseases prevalent in tropical and subtropical regions. They disproportionately affect marginalized populations living in poverty.

Examples of NTDs

- **Noma (Cancrum Oris):** A severe gangrenous disease of the mouth and face, primarily affecting malnourished children aged 2-6 years.
- Other NTDs include **dengue**, **chikungunya**, **rabies**, **leishmaniasis**, **leprosy**, and **lymphatic filariasis**.

Initiatives: The **London Declaration on Neglected Tropical Diseases 2012** and the **Kigali Declaration on Neglected Tropical Diseases 2022**

LIFESTYLE DISEASES

- **Lifestyle diseases** are linked to unhealthy behaviors often associated with modern living, including poor diet, lack of physical activity, and substance abuse.

Common Lifestyle Diseases

- **Asthma:** Triggered by environmental factors such as pollution, exacerbated by a sedentary lifestyle. Requires a balanced approach to management.
- **Tobacco-Induced Diseases:** Includes **COPD**, lung cancer, and heart diseases, stemming from both smoking and passive smoking. Tobacco cessation is crucial for prevention.
- **Obesity:** Results from excessive calorie intake and physical inactivity. A significant risk factor for CVDs and diabetes. Management involves a balanced diet and regular exercise.
- **Hypertension (High Blood Pressure):** Often due to stress, high salt intake, and obesity. It is a critical risk factor for heart diseases and stroke. Lifestyle changes can help manage blood pressure.
- **Mental Health Disorders:** Increasingly prevalent due to modern lifestyle pressures, with social isolation and work-related stress being major contributors. Physical activity and social engagement are vital for mental health maintenance.

RARE DISEASES

India currently does not have a standard definition, but the Organisation of Rare Diseases India (ORDI) has suggested that a disease is to be defined as rare if it affects 1 in 5,000 people or less. Approximately **450 rare diseases** are documented in India.

Common Rare Diseases Include:

- Autoimmune diseases, Gaucher's disease, hemophilia, sickle cell anemia, thalassemia, and certain types of muscular dystrophies.

Government Initiatives: The **National Policy for Treatment of Rare Diseases, 2021** classifies rare diseases into three groups based on treatment needs, offering financial assistance and establishing specialized treatment centers.

NUTRITIONAL DISEASES

Nutritional inadequacy indicates insufficient nutrient intake, while **nutritional deficiency** signifies critically low levels of nutrients that impair bodily functions.

Types of Nutritional Diseases:

- **Macronutrient Deficiency:**
  - **Protein-Energy Malnutrition (PEM):** Prevalent in developing countries, characterized by insufficient protein and energy intake.
    - **Marasmus:** Severe undernutrition leading to extreme weight loss and emaciation.
    - **Kwashiorkor:** Resulting from severe protein deficiency, often in children weaned from breast milk, leading to symptoms like a swollen belly (edema). (RAS 2024)
- **Ketosis:** Arises from long-term carbohydrate insufficiency, characterized by elevated ketone bodies, often marked by a sweet odor on the breath.
- **Essential Fatty Acid Deficiency:** A low **omega-3 index** is associated with an increased risk of mortality from coronary heart disease. **Omega-3 and omega-6 fatty acids** are crucial for cardiovascular health.

Micronutrient Deficiency

Micronutrient	Deficiency Disease/Symptoms
Vitamin A	Xerophthalmia, Bitot spots, night blindness, keratomalacia, and permanent blindness
Vitamin B1	Beriberi (wet beriberi affects cardio-vascular system; dry beriberi affects CNS, causing impaired motor function and numbness)
Vitamin B3	Pellagra (dermatitis, dementia, diarrhea)
Vitamin B6	Anaemia, peripheral neuropathy, sebo-rrheic dermatitis, glossitis, depression, seizures
Vitamin B12	Megaloblastic anaemia, fatigue, weakness
Vitamin B9	Megaloblastic anaemia, pancytopenia, glossitis, oral ulcers
Vitamin C	Scurvy (gum disease), behavioural and mood changes
Vitamin D	Hypocalcemia, hypophosphatemia, rickets (children), osteomalacia (adults)
Vitamin E	Ataxia, myopathy, pigmented retinopathy, vision loss

Vitamin K	Coagulation disorder, hemorrhagic disease of newborns
Calcium	Cataracts, dental changes, osteoporosis, rickets, brain alterations
Iron	Microcytic hypochromic anaemia (small red blood cells, low hemoglobin)
Iodine	Goiter (thyroid enlargement)
Zinc	Skin lesions, infection susceptibility, night blindness, low sperm count, slow wound healing
Magnesium	Linked with colorectal cancer, osteoporosis, hypertension, metabolic syndrome, diabetes
Selenium	Keshan disease (cardiomyopathy), Kashin-Bek disease (arthritis), thyroid issues, immune problems
Fluoride	Dental caries, bone problems
Biotin	Metabolic acidosis, developmental delay, seizures, hair loss, dermatitis

Food Fortification

It is the practice of adding vitamins and minerals to commonly consumed foods during processing to increase their nutritional value and is a proven, safe and cost-effective strategy for improving diets and for the prevention and control of micronutrient deficiencies.

Probiotics are foods/supplements that contain live microorganisms (Bacteria, Yeast) intended to maintain or improve the 'good' bacteria (normal microflora) in the body.

DRUGS AND MEDICINES

Definition

- **Drugs:** Chemical substances that alter physiological functions in living organisms. They can be **natural** (from plants, animals, or minerals) or **synthetic** (manufactured in labs).
- **Medicines:** Therapeutically active drugs used for the diagnosis, treatment, or prevention of diseases.

Mechanism of Action

- Drugs target specific macromolecules (e.g., proteins, receptors) to generate biological responses, often affecting the **nervous system**. They can be toxic at high doses (lethal doses).

Regulatory Framework in India

Drugs and Cosmetics Act, 1940

- Regulates the **import, manufacture, distribution, and sale** of drugs and cosmetics in India.

Key Regulatory Authorities

- Central Drugs Standard Control Organization (CDSCO)
- State Drug Control Authorities
- Drug Controller General of India (DCGI)

Drug Price Control Order (DPCO) Act

- Established under the **Essential Commodities Act, 1955**, this act empowers the **National Pharmaceutical Pricing Authority (NPPA)** to regulate the prices of essential medicines.

Products Covered Under DPCO

1. **Essential Medicines:** Listed in the **National List of Essential Medicines (NLEM)** for treating critical conditions (e.g., diabetes, hypertension).
2. **Life-saving Drugs:** Treat life-threatening diseases (e.g., cancer, HIV/AIDS).
3. **Generic Medicines:** Non-branded versions of drugs, providing cost-effective alternatives.
4. **Medical Devices:** Includes cardiac stents, orthopedic implants, etc.
5. **Bulk Drugs:** Active Pharmaceutical Ingredients (APIs) for drug manufacturing.

FATS

Overview of Lipids

- **Lipids** are generally water-insoluble organic compounds essential for various biological functions. They include fats, oils, waxes, and steroids.
- **Fatty Acids:** The building blocks of fats, characterized by a carboxyl group (–COOH) attached to a hydrocarbon chain (R group). Fatty acids can be classified into:
  - **Saturated Fatty Acids:** Contain only single bonds (C–C) between carbon atoms.
  - **Unsaturated Fatty Acids:** Contain one or more double bonds (C=C) within the carbon chain.

Saturated Fats

- Composed solely of single bonds between carbon atoms, resulting in the maximum number of hydrogen atoms bonded to each carbon.
- **Characteristics:**
  - Typically solid at room temperature (e.g., butter, lard).
  - More stable and less prone to rancidity compared to unsaturated fats.
  - Mostly found in animal fats but also present in some plant oils (e.g., coconut oil).

Unsaturated Fats

- Contain at least one double bond in their structure, resulting in fewer hydrogen atoms.

- **Characteristics:**
  - Generally liquid at room temperature (e.g., olive oil, fish oil).
  - More vulnerable to rancidity due to oxidation.
  - Healthier compared to saturated fats, offering benefits like improved heart health.

Cholesterol

- **Cholesterol** is a fat-like, waxy substance synthesized mainly in the liver. It is essential for:
  - Formation of cell membranes.
  - Synthesis of hormones (e.g., estrogen, testosterone).
  - Production of vitamin D and bile acids that aid in digestion.
  - Normal Blood Cholesterol:
  - Total: < 200 mg/dL
  - LDL: < 100 mg/dL
  - HDL: > 40 mg/dL (men), > 50 mg/dL (women)

Types of Cholesterol

1. **Low-Density Lipoproteins (LDL):** Known as "bad" cholesterol, high levels can lead to plaque buildup in arteries, increasing the risk of heart disease.
2. **High-Density Lipoproteins (HDL):** Known as "good" cholesterol, it helps remove LDL cholesterol from the bloodstream, protecting against heart disease.

Trans Fats

- **Trans fats**, or trans-fatty acids (TFAs), are a type of unsaturated fat that can be found in both natural and industrial forms.
- **Health Risks:** Linked to increased risk of cardiovascular diseases by raising LDL cholesterol and lowering HDL cholesterol.

Types of Trans Fats

1. **Naturally Occurring Trans Fats:** Found in small amounts in some animal products (e.g., meat, dairy) due to microbial fermentation in ruminants.
2. **Artificial Trans Fats:** Created through hydrogenation, a process that converts liquid oils into solid fats, commonly found in partially hydrogenated oils (PHOs).

Sources of Trans Fats

- **Natural Sources:** Ruminant animals (cattle, sheep), dairy products, and some meats.
- **Industrial Sources:** Used in processed foods, baked goods, margarine, and fast food.

Global Initiatives to Eliminate Trans Fats

- **REPLACE Campaign:** Launched by WHO in 2018 to eliminate industrially produced trans fats globally by 2023.
- **Denmark:** First country to ban trans fats in 2003.
- **United States:** FDA banned artificial trans fats in 2015.

Indian Initiatives Against Trans Fats

1. **FSSAI Initiative-Trans Fat Free Logo:** A voluntary labeling initiative promoting trans-fat-free products.
2. **Heart-Attack Rewind Campaign:** Launched in 2018 to reduce bad cholesterol from the food supply, targeting a reduction of trans fat consumption below 2%.
3. **RUCO (Repurpose Used Cooking Oil) Initiative:** Promotes the safe disposal and recycling of used cooking oil into biodiesel, addressing health risks and promoting sustainability.

Eat Right Movement

- **Eat Right India** is an initiative by the Government of India and FSSAI, promoting safe, healthy, and sustainable food practices.

FOOD ADULTERATION

- **Food Adulteration** refers to the intentional or unintentional addition of substances that degrade food quality and safety, considered a criminal offense if it violates food safety standards.

Type of Adulteration	Example	Impurity
Intentional Adulteration	Rice	Plastic rice (synthetic starch grains)
	Chili Powder	Brick powder or artificial color (red lead oxide)
	Coffee Powder	Chicory powder (to increase weight)
Incidental Adulteration	Fruits and Vegetables	Pesticide residues or insecticides
	Flour	Rodent droppings or insects
	Honey	Sugar syrup or glucose (to increase sweetness)
Metallic Adulteration	Rice	Lead or mercury (from contaminated water)
	Black Salt	Iron filings

ANTIMICROBIAL RESISTANCE (AMR)

Definition: Occurs when microbes (bacteria, viruses, fungi, parasites) no longer respond to antimicrobial medicines (antibiotics, antivirals, antifungals, antiparasitics).

How does Antibiotic Resistance Occur?

High number of bacteria. A few of them are resistant to antibiotics.

Antibiotics kill bacteria causing the illness, as well as good bacteria protecting the body from infection.

The resistant bacteria now have preferred conditions to grow and take over.

Bacteria can even transfer their drug-resistance to other bacteria, causing more problems.

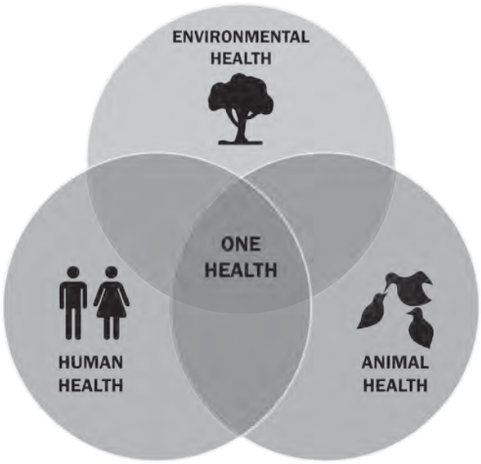
- **Causes:** Natural process influenced by genetic changes in pathogens, accelerated by human misuse and overuse of antimicrobials.
- **Consequences:** Resistance makes infections difficult or impossible to treat.
- **Role of Vaccines:** Help prevent diseases and reduce antibiotic misuse.

BIOFILM

Biofilms can form on medical implants within human tissues. Biofilms can form on food and food processing surfaces.Biofilms can exhibit antibiotic resistance

One Health Approach

- **Definition:** A holistic strategy recognizing the inter-connection between human, animal, and environmental health.
- **Issues Addressed**: Ecosystem degradation, zoonotic diseases, and AMR.
- **Global Collaboration**: One Health Joint Plan of Action (2022-26) involves FAO, UNEP, WHO, and the World Organisation for Animal Health to tackle health threats.



- **India's Initiative**: National One Health Mission by the Office of the Principal Scientific Advisor aims to coordinate One Health efforts, including:
  - **Animal Pandemic Preparedness Initiative (APPI)**
  - **Animal Health System Support for One Health (AHSSOH)**, funded by the World Bank.

Traditional Medicine System

- **Definition**: Encompasses knowledge and practices based on indigenous beliefs to maintain health and treat illnesses.
- **Major Systems in India**: Ayurveda, Yoga, Naturopathy, Unani, Siddha, Sowa Rigpa, and Homeopathy (AYUSH).
- **Government Support**: The Ministry of AYUSH promotes research and integration into mainstream healthcare.
- **Traditional Knowledge Digital Library (TKDL)**: Preserves knowledge related to Indian medicine systems.
- **WHO Endorsement**: Recognizes the role of traditional medicine in achieving Universal Health Coverage (UHC).
- **Ayurveda**, originating in India during the ancient Vedic period, is based on the balance of **three doshas—Vata (air), Pitta (fire), and Kapha (water)**—and focuses on body-mind harmony, preventive health, and rejuvenation through natural remedies.
- **Yoga**, also originating in India, emphasizes the union of mind, body, and spirit through physical postures **(Asanas)**, breathing exercises **(Pranayama)**, and meditation **(Dhyana)**.
- **Naturopathy** is based on the healing power of nature and uses elements such as diet therapy, fasting, and hydrotherapy for holistic health.
- The **Unani** system, which originated in Greece and was introduced to India by Arabs, is built around the

theory of **four humors** (blood, phlegm, yellow bile, and black bile), aiming to balance these humors for maintaining health.

- **Siddha**, a traditional system practiced primarily in South India, is based on the **Pancha Boothas** (five elements) and **three humors** (Vata, Pitta, Kapha), using herbs, minerals, and diet to maintain bodily balance.
- **Sowa Rigpa**, also known as the **Amchi** system, is a traditional Tibetan medicine influenced by **Ayurveda**. It is based on similar principles, such as the **five elements** and the balance of humors, and is largely derived from the **Ashtanga Hridaya**, a key Ayurvedic text. This system has been enriched in Tibet and is practiced in regions like **China**, the **Himalayan regions of India, Mongolia, Nepal, Russia**, and **Bhutan**.
- **Homeopathy**, developed in the 18th century by Samuel Hahnemann in Germany, is based on the principle of "**like cures like**" and uses highly diluted substances to treat diseases, providing individualized treatments for holistic health. These traditional medicine systems play a vital role in global healthcare, integrating ancient knowledge with modern wellness practices.

Global Centre for Traditional Medicine (GCTM)

- **Location**: Jamnagar, Gujarat, India.
- **Purpose**: First global knowledge centre for traditional medicine.
- **Financial Commitment**: India has committed approximately US$ 250 million to support its establishment and operations.

ASSISTED REPRODUCTIVE TECHNOLOGY (ART) AND SURROGACY

ART refers to medical techniques used to address infertility, defined by the WHO as the inability to conceive after one year without contraception. It includes procedures like in vitro fertilization (IVF), artificial insemination, and surrogacy. Common ART methods are:

1. **In Vitro Fertilization (IVF):** Fertilization occurs outside the body.
2. **Gamete Intrafallopian Transfer (GIFT):** Transfer of eggs and sperm into the fallopian tubes for fertilization.
3. **Zygote Intrafallopian Transfer (ZIFT):** Fertilization occurs outside, and the embryo is placed in the fallopian tube.
4. **Intracytoplasmic Sperm Injection (ICSI):** A single sperm is injected into a mature egg, used for male infertility or failed IVF attempts.
5. **Artificial Insemination:** Deliberate introduction of sperm into the female's cervix or uterus, including:
   - Intrauterine insemination
   - Intracervical insemination
   - Intratubal insemination

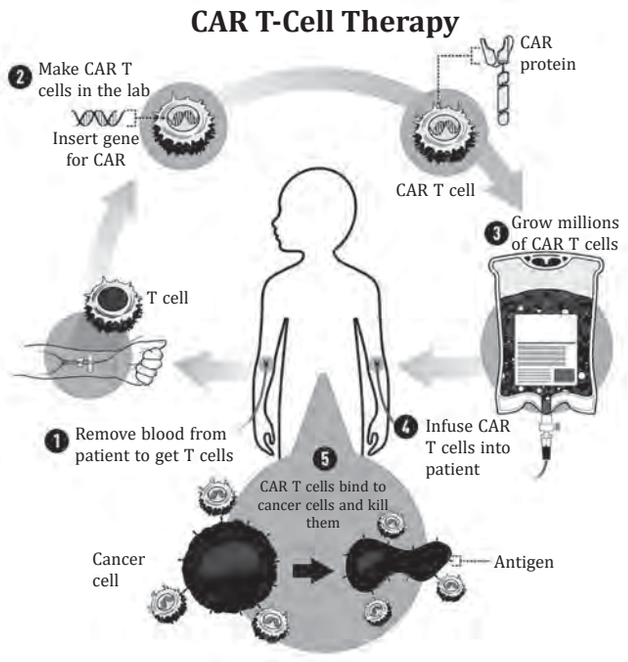
Surrogacy

Surrogacy involves a woman (surrogate) agreeing to carry a child for another person or couple.

- **Altruistic Surrogacy:** No monetary compensation other than medical expenses.
- **Commercial Surrogacy:** Monetary compensation beyond medical costs.

CAR-T CELL THERAPY

CAR-T cell therapy is a type of cellular immunotherapy that genetically **alters T cells** in a laboratory **to enhance their ability to locate and destroy cancer cells.** T cells are immune cells that attack pathogens (viruses, bacteria, fungi, and parasites) as well as harmful cells like cancer cells.


CAR T-Cell Therapy
2 Make CAR T cells in the lab
Insert gene for CAR
CAR protein
CAR T cell
3 Grow millions of CAR T cells
T cell
1 Remove blood from patient to get T cells
4 Infuse CAR T cells into patient
5 CAR T cells bind to cancer cells and kill them
Cancer cell
Antigen

The Central Drugs Standard Control Organisation (CDSCO) has approved **NexCar19**, an indigenous CAR-T cell therapy developed by ImmunoACT, a company incubated at IIT Bombay. The CDSCO functions as the Central Drug Authority, overseeing drug import regulations, new drug approvals, and clinical trials under the Drugs and Cosmetics Act of 1940.

VACCINATION PROGRAM

The vaccination program is a **revolutionary step** in the direction of public health, whose main objective is to provide protection to the society from life-threatening diseases. It breaks the cycle of infection by increasing the body's immunity and plays a decisive role in reducing infant mortality rates. Programs like India's **'Intensified Mission Indradhanush'** are proof that through collective efforts we are capable of eradicating diseases like polio and smallpox from the roots.

Vaccination Program at Global Level

- **Start:** Year 1974 AD.
- **Organization:** The foundation of this program was laid by the World Health Organization (WHO).
- **Context of India:** India adopted this global initiative in the year **1978**.

Main Objectives

- **Infant Protection:** Protecting children worldwide from those diseases that can be prevented through vaccination.
- **Mortality Rate:** Effectively reducing the infant mortality rate.

Initial Target Diseases (06 Major Diseases)

- The goal was set to provide protection against the following **six diseases**.

1. **Tuberculosis:** For this, the **BCG** vaccine is administered.
2. **Polio:** For protection against disability.
3. **Diphtheria:** Serious respiratory infection.
4. **Pertussis:** Which is also called whooping cough.
5. **Tetanus:** Infection affecting the nervous system.
6. **Measles:** Highly contagious viral disease.

VACCINATION PROGRAM IN INDIA

India's vaccination campaign is one of the largest and most successful public health programs in the world, which is the result of decades of continuous efforts.

Gradual Development of the Program

- **1978:** 'Expanded Programme on Immunization' (**EPI**) was started in India.
- **1985:** The name of the program was changed to **'Universal Immunization Programme'** (**UIP**) and it was expanded from urban areas to rural areas.
- **1992:** It was made a part of the 'Child Survival and Safe Motherhood' (**CSSM**) program.
- **1997:** It was included in the 'National Reproductive and Child Health' (**RCH**) program.
- **2005:** With the formation of the 'National Rural Health Mission' (**NRHM**), UIP became an integral part of it.

Importance and Target of UIP

- **Global Level:** It is included among the largest public health programs in the world.
- **Annual Target:** Under the program, a target is set for the vaccination of approximately **2.67 crore newborn babies** and **2.9 crore pregnant women** every year.
- **Impact:** It has played a decisive role in reducing the mortality rate of children under 5 years of age.

Diseases Covered Under UIP

- Vaccination has been divided into **two levels**:
- **At National Level (09 Diseases):** Protection is provided to all children across the country against these 9 diseases-
  - Diphtheria, Pertussis (whooping cough), and Tetanus.
  - Polio, Measles, and Rubella.
  - Severe form of childhood Tuberculosis.
  - Hepatitis-B and Meningitis & Pneumonia caused by Hib.
- **At Sub-National Level (03 Diseases):** These are administered according to the requirement of specific regions or states-
  - Rotavirus diarrhea.
  - Pneumococcal pneumonia.
  - Japanese Encephalitis (only in those districts where this disease is endemic).

Major Achievements and Modern Initiatives

- **Eradication: Polio in the year 2014** and **Maternal & Neonatal Tetanus in the year 2015** were successfully eradicated.
- **COVID-19 Vaccination (2021-23):** The world's largest vaccination campaign with massive coverage was conducted, which contributed at the global level.
- **Safety Surveillance (AEFI):** A national system named **AEFI** (Adverse Events Following Immunization) is functioning to monitor any adverse event occurring after vaccination.

VACCINATION IN RAJASTHAN: HISTORIC ACHIEVEMENT OF 91.8 PERCENT

- **Medical and Health Minister Gajendra Singh Khimsar** shared the vaccination data of the state on the occasion of **National Vaccination Day (16 March, 2026)**.
- **Historic Growth:** The percentage of full vaccination in Rajasthan has increased over the last **three decades** from **21.1% (1992-93)** to reach **91.8% (2024-2025)**.
- **Recent Progress:** In the **year 2021-22** it was **83.3%**, which continuously increased and reached **88.2% in the year 2023-24**.
- **National Comparison:** The vaccination level of Rajasthan is **4 points higher than the national average**, which reflects the state's robust health system.
- **Positive Impact:** Due to increasing vaccination coverage, **maternal and infant mortality rates** have rapidly declined in the state and the situation is better than the national average.
- **Polio Status:** No case of polio has been found in Rajasthan after the **year 2009**. It is noteworthy that **India has already been declared polio-free in 2014**.

Why in the News?

AdFalciVax Vaccine

- **Introduction:** This is India's first indigenous multi-stage malaria vaccine.
- **License:** The Government of India has granted licenses to private companies for its manufacture.
- **Developer:** This vaccine is being jointly developed by the Department of Biotechnology (DBT) and the National Institute of Immunology (NII).
- **Collaborating Institutions:** The Regional Medical Research Centre of ICMR (Bhubaneswar) and the National Institute of Malaria Research (NIMR) are collaborating on this project.

Technical Features and Working Mechanism

- **Main Target:** This vaccine targets Plasmodium falciparum (the most lethal parasite species of malaria).
- **Multi-Stage Approach:** While existing vaccines target only one life stage, AdFalciVax attacks **two crucial stages** of the parasite's life cycle:
  - **Pre-erythrocytic (Liver) stage:** To prevent the infection from spreading in the body.
  - **Transmission (Sexual) stage:** To prevent the spread of the parasite from one person to another person.
- **Recombinant Chimeric Vaccine:** It is called a "chimeric" vaccine because it combines antigens derived from various stages of the parasite into a single immunogen.

Nafithromycin

- This is India's first indigenously discovered antibiotic.
- **Development:** Developed by the private company 'Wockhardt' in collaboration with the Biotechnology Industry Research Assistance Council (BIRAC), which comes under the Department of Biotechnology (DBT).
- **Brand Name:** It will be sold in the market under the name 'Miqnaf'.

SEVERAL MODERN INITIATIVES IN VACCINE LOGISTICS AND COLD CHAIN MANAGEMENT

Capacity Building

- Dedicated training centers have been established for the technical maintenance of the vaccination system.
- **Major Institutions:**
  - **National Cold Chain Training Centre (NCCTE):** Pune.
  - **National Cold Chain and Vaccine Management Resource Centre (NCCVMRC):** NIHFW, New Delhi.
- **Main Objective:** To provide technical training to cold chain technicians for the repair and maintenance of equipment.

Electronic Vaccine Intelligence Network (eVIN)

- **Function:** Digital tracking of vaccine stock, logistics, and storage temperature.
- **This is an innovative technological solution focusing on the digitalization of the vaccine supply chain.**
- **Coverage:** Its expansion ranges from the national level to the state, district, and sub-district levels.
- **Major Benefits:**
  - **Real-time monitoring** of vaccine stock and temperature.
  - Providing an overall overview of cold chain logistics.

Stages of eVIN:

1. **First Stage (12 States):** Rajasthan, Uttar Pradesh, Madhya Pradesh, Gujarat, Bihar, Assam, Chhattisgarh, Himachal Pradesh, Jharkhand, Manipur, Nagaland, and Odisha.
2. **Second Stage (9 States/UTs):** Karnataka, Maharashtra, Telangana, Andhra Pradesh, Goa, Tripura, Uttarakhand, Daman and Diu, Dadra and Nagar Haveli.

- **Ultimate Goal:** To expand this technology across the entire country.

National Cold Chain Management Information System (NCCMIS)

- This system functions as a **comprehensive database** for the **management of cold chain equipment**.
- **Main Objective:** Continuous monitoring of cold chain equipment, which includes:
  - **Inventory:** Management of the total list of equipment.
  - **Availability:** Ensuring that equipment is available at the right place.
  - **Efficiency:** Continuous monitoring of the working condition of the equipment.

Economic Review 2025-26: Key Data of Health Sector

A. Major Achievements in the Health Sector

- **Reduction in Mortality Rate:** A remarkable reduction of 86% has been recorded in the Maternal Mortality Ratio (MMR) since the year 1990.
- **Child Mortality Rate:** A decline of 78% has been recorded in the Under-Five Mortality Rate (U5MR), which is faster than the global average.

- **Digital Health:** Ayushman Bharat Digital Mission (ABDM) has facilitated access to health services.
- **Tele-consultation:** Tele-consultation in remote areas has become possible through 'e-Sanjeevani'.
- **Use of AI:** Artificial Intelligence (AI) is being used in the screening of TB and the identification of diabetes-related eye diseases.

B. Change in the Pattern of Pandemic (Double Burden)

- **Double Challenge:** India is currently facing the dual challenge of Communicable Diseases (CDs) and rapidly increasing Non-Communicable Diseases (NCDs).
- **Impact of NCDs:** 57% of total deaths occurring in the country are due to Non-Communicable Diseases (NCDs), among which heart disease is the most prominent.

C. Challenge of Obesity and Policy Measures

- **Current Status:** 24% of women and 23% of men in the country suffer from being overweight or obese.
- **Future Projection:** The level of obesity in children is projected to reach 8.3 crore by the year 2035.
- **Ultra-Processed Food (UPF):** There has been a 40-fold increase in the sale of UPF between the years 2006 and 2019, which is the major cause of increasing obesity.
- **Suggestions:** Fixing a clear definition of UPF, implementing strict labeling rules, and considering the imposition of a GST surcharge on food items high in sugar, salt, and fat.

D. Nutrition and Behavioral Change

- **Improvement in Intake:** The level of calorie and protein intake has improved across all income groups.
- **Equality:** The level of nutritional intake in rural and urban areas has now become largely equal.
- **Rajasthan's 'Cash Plus' Model:** This model (DBT + behavioral change) has been successful in reducing malnutrition indicators like wasting and stunting.

E. Digital Addiction: New Health Challenge

- **Spread:** With access to smartphones reaching 85.5% of households in the country, digital addiction is increasing among youth.
- **Impact:** This situation is adversely affecting mental health and sleep quality.

GOVERNMENT INITIATIVES TOWARDS STRENGTHENING PUBLIC HEALTH

Public health is the foundational pillar of progress for any nation, for which the government is continuously making efforts at both **preventive and curative** levels. To increase the immunity of citizens, a war is being fought against malnutrition through comprehensive vaccination campaigns like 'Mission Indradhanush' to 'Poshan Abhiyaan'. Along with this, by making health services universally accessible through schemes like 'Ayushman Bharat', the government is not only moving forward to stop the spread of communicable diseases but also towards building a **'Healthy and Capable India'**.

MAJOR EFFORTS

Ayushman Bharat

- This is the world's largest government-funded healthcare scheme, which is also known by the name **'Pradhan Mantri Jan Arogya Yojana' (PM-JAY)**.
- **Announcement:** February 2018
- **Launch:** September 2018
- **Nodal Ministry:** Ministry of Health and Family Welfare, Government of India.
- **Implementation Agency:** National Health Authority (NHA)

Main Objectives of the Scheme

- **Infrastructure Development:** Developing a robust public health infrastructure in urban and rural areas.
- **Health Coverage:** Achieving the goal of **Universal Health Coverage**.

Beneficiaries and Coverage

- **Eligibility:** BPL (Below Poverty Line) families and workers in the unorganized sector are its main beneficiaries.
- **Insurance Amount:** Health insurance of **₹5 lakh** per family per year.
- **Outreach:** Currently, more than 50 crore people from 10.37 crore families have been targeted.

Two Major Components of the Scheme

I. Health and Wellness Centers (Arogya Mandir)

- **Target:** More than 1.5 lakh "Healthcare Centers" are being opened across the country.
- **Function:** Providing primary healthcare services and focusing on the prevention of diseases.

II. Pradhan Mantri Jan Arogya Yojana (PM-JAY)

- **Insurance Security:** Cashless insurance up to ₹5 lakh for the treatment of serious illnesses.
- **Enrollment:** Currently, more than 10 crore families are enrolled under this scheme.

AYUSHMAN BHARAT DIGITAL HEALTH MISSION (ABDM)

- **Launch:** This mission was started on 27 September, 2021.

- **Objective:** To digitalize healthcare services across the country and create an integrated digital health ecosystem.

Key Features:

- **Ayushman Bharat Health Account (ABHA):** Under this, a unique health ID will be created for every Indian citizen.
- **Digital Records:** Through this ID, citizens will be able to keep their health records (such as lab reports, prescriptions, and discharge summaries) digitally secure and share them with doctors.
- **ID Structure:** This health ID will be a unique number of **14 digits**.
- **Integration at National Level:** This will enable the creation of a nationwide digital health system, making the treatment process more accessible and transparent.

NATIONAL HEALTH MISSION (NHM)

- **Launch:** The National Health Mission was started in the year 2013.
- **Sub-Missions:** Under this, two major sub-missions are operated:

1. **National Rural Health Mission (NRHM):** It was started in the year 2005 and focuses on areas with a population of less than 50,000.
2. **National Urban Health Mission (NUHM):** It was started in the year 2013 and is for urban areas with a population of more than 50,000.

Main Objectives:

- Strengthening the health system of urban and rural areas.
- **Maternal Mortality Ratio (MMR):** To reduce it to the level of 1/1000 per live births.
- **Infant Mortality Rate (IMR):** To reduce it to the level of 25/1000 per live births.
- **Fertility Rate:** To bring the Total Fertility Rate (TFR) to the level of 2.1.
- Effective prevention and control of communicable and non-communicable diseases.

The following programs/schemes are operated by the government under the National Health Mission:

Reproductive, Maternal, Newborn, Child and Adolescent Health	Communicable Diseases	Non-Communicable Diseases	National Nutrition Programme
❖ Janani Shishu Suraksha Karyakram (JSSK) ❖ Rashtriya Kishor Swasthya Karyakram (RKSK) ❖ Rashtriya Bal Swasthya Karyakram (RBSK) ❖ Universal Immunization Programme ❖ Mission Indradhanush (MI) ❖ Janani Suraksha Yojana (JSY) ❖ Pradhan Mantri Surakshit Matritva Abhiyan (PMSMA) ❖ Navajat Shishu Suraksha Karyakram (NSSK) ❖ National Family Planning Programme ❖ LaQshya Karyakram (Labour Room Quality Improvement Initiative)	❖ Integrated Disease Surveillance Programme (IDSP) ❖ Revised National Tuberculosis Control Programme (RNTCP) ❖ National Leprosy Eradication Programme (NLEP) ❖ National Vector Borne Disease Control Programme (NVBDCP) ❖ National AIDS Control Programme (NACP) ❖ Pulse Polio Programme ❖ National Viral Hepatitis Control Programme (NVHCP) ❖ National Rabies Control Programme ❖ National Programme on Containment of Antimicrobial Resistance (AMR)	❖ National Tobacco Control Programme (NTCP) ❖ National Programme for Prevention and Control of Cancer, Diabetes, Cardiovascular Diseases and Stroke (NPCDCS) ❖ National Programme for Control and Treatment of Occupational Diseases ❖ National Programme for Prevention and Control of Deafness (NPPCD) ❖ National Mental Health Programme ❖ National Programme for Control of Blindness and Visual Impairment (NPCBVI) ❖ Pradhan Mantri National Dialysis Programme (PMNDP) ❖ National Programme for the Health Care of Elderly (NPHCE) ❖ National Programme for Prevention and Management of Burn Injuries (NPPMBI) ❖ The National Oral Health Programme	❖ National Iodine Deficiency Disorders Control Programme ❖ MAA (Mothers' Absolute Affection) Programme for Infant and Young Child Feeding ❖ National Programme for Prevention and Control of Fluorosis (NPPCF) ❖ National Iron Plus Initiative for Anaemia Control

National One Health Mission (NOHM)

- **Introduction:** The Government of India has launched the 'National One Health Mission' to integrate human, livestock, wildlife, and environmental health into a single thread.
- **Vision:** This is a multi-sectoral initiative, which is based on an integrated health approach.

Main Objectives of the Mission:

- **Integrated Surveillance:** To improve the surveillance and identification of diseases across different sectors.
- **Disease Response:** To strengthen diagnosis and the response provided during disease outbreaks.

Institutional Framework:

- **Nodal Agency:** This mission is being operated by the **Indian Council of Medical Research (ICMR)** under the office of the 'Principal Scientific Adviser' (PSA).
- **Key Institution: National Institute of One Health, Nagpur** is the main center for the implementation and research of this mission.

Need and Importance of the Mission:

1. **Zoonotic Risk:** To reduce the risk of diseases spreading from animals to humans.
2. **Pandemic Prevention:** To ensure better alertness and preparedness against future pandemics.
3. **Antimicrobial Resistance (AMR):** To control the increasing resistance against medicines.
4. **Environmental Balance:** To secure human life by protecting the health of the environment and wildlife.

JANANI SURAKSHA YOJANA

- **Launch:** This scheme was launched on April 12, 2005.
- **Nature of the Scheme:** This is a 100 percent Centrally Sponsored Scheme.
- **Objective:** To reduce maternal and infant mortality rates by promoting institutional delivery among pregnant women.

Financial Assistance (Cash Assistance):

Under the scheme, assistance is provided to beneficiaries and Asha Sahyoginis as follows:

- **Rural Area:** Rs. 1400 is given to the pregnant woman and Rs. 600 is given to the Asha Sahyogini.
- **Urban Area:** Rs. 1000 is given to the pregnant woman and Rs. 400 is given to the Asha Sahyogini.

Beneficiary and Eligibility:

- Mainly women from BPL families.
- The age of the beneficiary should not be less than 19 years.

Key Features:

- **Special Focus:** This scheme gives special focus to those states where the rate of institutional delivery is low.

NATIONAL NUTRITION MISSION

- **Launch:** This mission was launched on March 8, 2018.
- **Location:** It was launched from Jhunjhunu (Rajasthan).
- **Ministry:** It comes under the Ministry of Women and Child Development.

Main Objectives:

- To improve the nutritional level of children below 6 years of age.
- To enhance the nutritional status of pregnant women.
- To improve the health and nutrition of lactating mothers.

Targets Set:

Under the mission, the following annual targets have been set to eradicate malnutrition:

- **Stunting:** To reduce this by 2% annually.
- **Under-nutrition:** To reduce this by 2% annually.
- **Low Birth Weight:** To reduce this by 2% annually.
- **Anemia:** To reduce this by 3% annually.

Special Fact:

Every year, the **month of September** is celebrated as 'National Nutrition Month'.

PM-POSHAN SCHEME (PM-POSHAN)

Pradhan Mantri Poshan Shakti Nirman Yojana

- **Announcement:** This scheme was announced in September 2021.
- **Duration:** This scheme has been approved for the period from 2021-22 to 2025-26.
- **Ministry:** It is operated under the Ministry of Education.
- **Objective:** To provide hot cooked meals to children in government and government-aided schools.

Key Features:

- **Replacement of Mid-Day Meal:** This scheme will replace the ongoing 'Mid-Day Meal' scheme, which covers about 11.8 crore children across 11 lakh schools in the country.
- **Foodgrain Distribution:** 100 grams and 150 grams of foodgrains will be provided to primary (class 1-5) and upper primary (class 6-8) children respectively.
- **Nutrition Gardens:** 'Nutrition Gardens' (Poshan Vatika) will be promoted in schools to give children firsthand experience of nature and gardening.
- **Special Supplementary Nutrition:** Provision for special supplementary nutritional items has been made for children in aspirational districts and those districts where the prevalence of anemia is high.
- **Social Audit:** To ensure transparency, 'Social Audit' of this scheme has been made mandatory in all districts.

MISSION INDRADHANUSH (MISSION INDRADHANUSH)

- **Launch:** This mission was launched on December 25, 2014.
- **Ministry:** It comes under the Ministry of Health and Family Welfare.
- **Objective:** To ensure complete vaccination of children up to 2 years of age and pregnant women.
- **Beneficiaries:** Those children and pregnant women who have missed vaccination or have been partially vaccinated.

Key Features:

- **Free Service:** Under the Universal Immunization Programme, all vaccines are provided free of cost.
- **Global Collaboration:** This mission receives financial and technical assistance from WHO (World Health Organization) and UNICEF.
- **Targeted Diseases:** It provides protection against 12 diseases - Diphtheria, Whooping Cough, Tetanus, Polio, TB, Hepatitis B, Pneumonia, Japanese Encephalitis, Measles, Rubella, and Haemophilus Influenzae Type-B.

INTENSIFIED MISSION INDRADHANUSH - IMI 5.0

- **Launch:** The intensified campaigns started in 2017.
- **Expansion:** Under IMI 5.0, for the first time, this campaign is being conducted across all districts of the country.
- **Change in Age Limit:** In this year's campaign, children up to 5 years of age have also been included (previously, this limit was 2 years).

Main Objectives and Digital Initiatives:

- **Vaccination Coverage:** To increase the coverage of all vaccines under the Universal Immunization Programme (UIP) according to the National Immunization Schedule (NIS).
- **Disease Eradication:** Special focus has been given to the target of eradicating Measles and Rubella by 2023.
- **Digital Platform:** The 'U-WIN' digital platform is being used in pilot mode across the country to monitor routine immunization.

PRADHAN MANTRI SURAKSHIT MATRITVA ABHIYAN

- **Launch:** This campaign was launched in the year 2016.
- **Objective:** To reduce Maternal Mortality Rate (MMR) and Infant Mortality Rate (IMR) through safe pregnancy and delivery.
- **Beneficiaries:** All pregnant women who are in their second or third trimester (after 4 months of pregnancy).

Key Features:

- **Fixed Day Service:** Special health check-up facilities are provided to all pregnant women on the **9th date** of every month.
- **Free Service:** Under this, antenatal care services are provided completely free of cost at all government health centers.
- **Specialist Check-up:** Doctors from the private sector are also encouraged to participate voluntarily so that ultrasound and other necessary tests can be made available to pregnant women.

SURAKSHIT MATRITVA AASHWASAN INITIATIVE (SUMAN)

- **Launch:** This initiative was launched on October 10, 2019.
- **Objective:** To provide free and quality healthcare services to all beneficiaries.
- **Beneficiaries:** Its primary beneficiaries are pregnant women and newborns.

Key Features:

- **Health Check-up:** Under this scheme, 4 free antenatal check-ups are provided.
- **Postnatal Care:** Free health check-ups for mother and child are conducted up to 6 months after the birth of the child.
- **Special Monitoring:** Special tracking arrangements have been made for high-risk pregnant women.

- **Emergency Facility:** Free ambulance (108 service) is provided to reach the health centers.

SICKLE CELL ANEMIA ELIMINATION MISSION

- **Announcement:** This mission was announced in the Union Budget 2023-24.
- **Target Year:** A target has been set for the complete elimination of sickle cell anemia from India by the year 2047.

Key Features:

- **Universal Screening:** Under this mission, universal screening of approximately 7 crore people aged 0 to 40 years living in tribal areas will be conducted.
- **Awareness and Treatment:** Identifying affected individuals through screening and providing them with counseling and necessary health facilities is a major part of this mission.
- **Focus Area:** This mission is specifically focused on those states and tribal areas where the prevalence of sickle cell disease is high.

NATIONAL HEALTH POLICY-2017 (NHP-2017)

- **Approval:** The Government of India has approved the new 'National Health Policy-2017' 15 years after the implementation of the National Health Policy-2002.
- **Basis:** This policy is based on the progress made since the last health policy (2002) and a background document titled "National Health Policy 2017 Situation Analysis".
- **Key Principles:** This policy is built on principles such as professionalism, integrity, ethics, equity, capability, universality, patient-centric care, accountability, and pluralism.

Main Objectives and Targets:

- **Universal Health Service:** To ensure the availability of assured healthcare services to all people, especially the underserved and neglected sections.
- **GDP Investment:** To increase government expenditure on health to **2.5% of GDP** by 2025.
- **Free Services:** To provide free drugs, diagnostics, emergency, and essential healthcare services in public hospitals.
- **Promotion of Yoga:** To effectively introduce Yoga in schools and workplaces to promote good health.
- **Role of Government:** To clarify the government's priorities regarding investment in the health sector, human resource development, access to technologies, and financial protection.

Four Main Reasons for the Change in Policy:

- The need for a new policy was felt due to the following changes that occurred after the previous policies (1983 and 2002):
- **Changing Priorities:** Maternal and child mortality rates have declined, but the burden of non-communicable diseases has increased.
- **Emerging Industry:** The healthcare industry is growing rapidly.
- **Catastrophic Expenditure:** Due to the rising cost of healthcare, the financial burden on people is increasing, which is a major cause of poverty.
- **Economic Growth:** Rising economic growth has strengthened the fiscal capacity of the government.

Expected Outcomes:

- To protect common citizens from the cost of treatment through financial security.
- To better strengthen and develop the 'human capital' of the country.
- To create a better health ecosystem by increasing collaboration among various government departments.

9 Food and Nutrition

INTRODUCTION TO NUTRITION

- **Basis of Life:** Nutrition is considered the primary basis of human life, without which the functioning and development of life are not possible.
- **Obtaining Substances:** Through the process of nutrition, any living organism obtains various types of essential substances from its surrounding environment.
- **Becoming a Part of the Body:** All these substances obtained from the environment become an integral part of the organism's body through the process of digestion.
- **Fulfillment of Needs:** After digestion, these nutrients help in fulfilling the various biological and physical needs of the organism's body.

Balanced Diet and Health

- **Necessity for Good Health:** To always maintain the human body in excellent and robust health, it is highly essential to regularly take a balanced diet.
- **Physical Strength:** A balanced diet makes the human body strong and powerful both internally and externally.
- **Increase in Immunity:** This diet protects the body from various types of diseases and boosts the body's disease-fighting capacity (immunity).
- **Development of Mental Health:** A balanced diet not only improves physical health but also makes the mind sharp, active, and completely healthy.
- **Effect of Lack of Healthy Food:** If the body does not receive healthy food for a long time, its absence leads to extreme fatigue in the body, and a person can become a victim of several types of serious diseases.

Classification of Nutrients

- **Basis of Classification:** Various nutrients present in food are mainly divided into two major categories based on their 'required quantity' for the body:

1. Macronutrients
2. Micronutrients

(A) Macronutrients

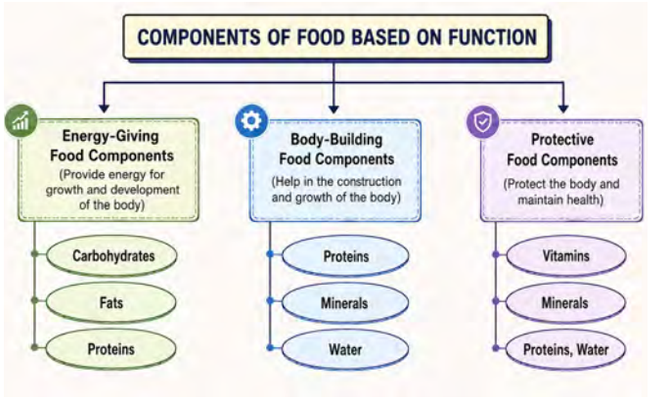
- **Definition:** Macronutrients are primarily those nutrients that the human body requires in large quantities.
- **Main Functions:** The primary function of these nutrients is to provide energy to the body for daily activities. Along with this, they play a crucial role in promoting the natural growth of the body and in the formation of new cells and tissues.
- **Types Included Under This:** This category mainly includes the following three nutrients:
  - Carbohydrates
  - Protein
  - Fat

(B) Micronutrients

- **Definition:** Micronutrients refer to those nutrients that the human body requires in very small or minute amounts (Small Quantity).
- **Main Functions:** Despite being required in small quantities, their main function is to regulate various biochemical processes within the body and to provide protection to the body against diseases.
- **Types Included Under This:** This category mainly includes the following two nutrients:
  - Vitamins
  - Minerals

Components of Food

- **Core Components:** Components of food refer to all those fundamental constituents and elements found in food that are essential for our body.
- **Physical Growth and Development:** These components are entirely instrumental in promoting the natural growth of the human body and ensuring its complete development.
- **Body Building:** The role of these components in the formation of new cells and tissues of the body is considered highly beneficial and important.
- **Protective Function:** All these components protect the body from various types of threats and prove to be completely beneficial for safeguarding health.



Carbohydrates

- **Main Source of Energy and Strength:** Carbohydrates are the most crucial and primary source for providing energy and strength to living organisms.
- **Primary Energy Source:** Carbohydrates (mainly in the form of starch and sugar) are considered the most prominent energy source for our human body.
- **Energy Value:** The complete oxidation of 1 gram of carbohydrate provides approximately 4 calories (kcal) of energy to the body.
- **Cheapest Source:** Although they are not the most concentrated source of energy, it is true that they are the cheapest source of energy for the body.
- **Share of Total Energy in Diet:** Generally, about 60% to 80% of the total dietary energy in our daily diet is provided by carbohydrates alone.
- **Effect of Deficiency (Hypoglycemia):** A deficiency of carbohydrates in food leads to a condition called 'Hypoglycemia' in the body, where the blood sugar level drops due to a lack of glucose, causing symptoms like dizziness, weakness, and fatigue.
- **Effect on Efficiency:** If carbohydrates are not adequately included in our daily diet, the overall working efficiency of our body will significantly decrease in their absence.

Chemical Composition

- **Mixture of Elements:** Carbohydrates are primarily composed of three elements – Carbon (C), Hydrogen (H), and Oxygen (O).
- **Fixed Ratio of Elements:** The chemical ratio of these elements—Carbon (C) : Hydrogen (H) : Oxygen (O) in carbohydrates is generally 1 : 2 : 1.
- **Exception to the Law of Ratio:** 'Deoxyribose Sugar' is a carbohydrate that does not follow this 1 : 2 : 1 ratio rule.

Storage in the Body

- **Storage in the Body:** Within our body, carbohydrates are primarily safely stored or accumulated in the form of 'glycogen'.
- **Process of Providing Energy:** This stored carbohydrate breaks down during the process of respiration and provides energy to the body according to its needs.
- **Physical Labor and Fatigue:** When we perform intensive physical labor such as playing, climbing heights, or running a large amount of our body's energy is consumed, and we get tired.
- **Utilization of Glucose:** To instantly regain this consumed energy, we drink an aqueous solution of glucose.
- **Reason for Instant Energy:** Glucose is actually that form of carbohydrate which provides instant energy to the body, which is why its consumption immediately gives energy to our body.
- **Normal Glucose Level:** The normal glucose level in human blood is less than 99 mg/dL on an empty stomach and less than 140 mg/dL after having a meal.

Major Sources of Carbohydrates

Carbohydrate sources in food can be mainly classified into two major parts:

- **Starchy Sources:** This mainly includes roti, rice, potato, grains, taro root (arbi), and banana.
- **Sugary Sources:** This mainly includes jaggery, sugar, dates, and raisins (munakka).

Types of Carbohydrates

Carbohydrates are mainly divided into three types based on their structure:

(A) Monosaccharides

- **Definition:** Monosaccharides are the simplest sugars that do not break down in water, containing 3 to 7 carbon atoms. They provide instant energy to the body.
- **Major Examples: (RAS 2018)**
  - **Glucose:** It is also called 'Blood sugar'.
  - **Fructose:** It is called the 'sugar of fruits and honey'; fructose is the sweetest natural sugar found in nature.
  - **Galactose:** It is an essential component of milk sugar.

(B) Oligosaccharides and Disaccharides

- **Oligosaccharides:** This is a type of carbohydrate that is formed by the joining together of 3 to 10 monosaccharide (simple sugar) units.
- **Disaccharides:** Upon undergoing the process of hydrolysis, disaccharides yield two monosaccharide molecules, which are linked together by a 'glycosidic bond'.
- **Major Examples: (RAS 2018)**
  - **Sucrose (Glucose + Fructose):** It is also called table sugar, kitchen sugar, or invert sugar.

- **Maltose (Glucose + Glucose):** It is called malt sugar.
- **Lactose (Glucose + Galactose):** It is called milk sugar.

(C) Polysaccharides

- **Definition:** Polysaccharides are complex sugars that yield numerous monosaccharide molecules upon hydrolysis, serving as a long-term source of energy for the body.
- **Major Examples and Their Specific Functions:**
  - **Starch:** This is the main form of food storage in plants. It is generally insoluble in water and its digestion is difficult, but heating makes its digestion easier.
  - **Glycogen:** This is the main form of glucose storage in animals.
  - **Cellulose:** It forms the cell wall of plants and functions as dietary fiber (roughage) in food. Our body does not contain enzymes for its digestion.
  - **Chitin:** It forms the exoskeleton of various insects.

Main Functions of Carbohydrates

- **Temperature Regulation:** Carbohydrates play an important role in balancing and regulating the internal temperature of our body.
- **Efficient Management of Organs:** It keeps every internal and external organ, tissue, and every living cell located in the body completely functional.

Chemical Testing of Starch/Carbohydrates

- **Method of Testing:** To test the presence of starch in food, an iodine solution is used.
- **Change in Color:** Starch gives a 'blue color' upon reacting chemically with the iodine solution, which fully confirms the presence of starch in the food.

Special Note: Colostrum

- **Definition:** Colostrum is the mother's first milk, which is secreted from the breasts for a few initial days immediately after the birth of the child.
- **Characteristics:** This milk is naturally thick and yellow in color. It contains the most abundant amount of an antibody named **IgA (Immunoglobulin A)** for the protection of the child.

Proteins (RAS 2023)

- **Origin of the Word:** The word 'protein' was first used by the scientist **Jons Jacob Berzelius**.
- **Quantity in the Human Body:** The total amount of protein in the human body is approximately **16–20%**.
- **Most Abundant Organic Compound:** The most abundant organic compound found in the human body is **collagen protein**.
- **Denaturation:** Heating a protein causes its denaturation, which alters its natural structure.
- **Body Building Food:** The primary function of protein is to manage the development of cells, their repair, and biochemical reactions; due to this specific function, protein is called **Body building food** (body-building nourishment).

Chemical Composition and Storage

- **Mixture of Elements:** Just like carbohydrates and fats, proteins are also compounds composed of Carbon (C), Hydrogen (H), and Oxygen (O).
- **Formation from Amino Acids:** Proteins are fundamentally made up of amino acid molecules, which are composed of Carbon, Hydrogen, Oxygen, and Nitrogen (N) elements.
- **Peptide Bond:** A total of 20 amino acids join together via peptide bonds to form a complete protein.
- **Role of Nitrogen & Sulphur:** It is primarily through proteins that our human body obtains nitrogen. Elements like nitrogen and sulphur are also included in this, which play important roles in several biological processes.
- **Presence in Protoplasm:** Apart from water, most of the remaining part of our protoplasm is primarily made up of protein.

Process of Protein Synthesis in the Body

- **Selection of Amino Acids:** Our body selects different amino acids according to its needs.
- **Synthesis of Specific Proteins:** After selection, the body recombines these amino acids to synthesize the specific proteins it requires.
- **Development of Cells and Tissues:** The cells and tissues of the body develop from these specific proteins that bind into new groups to form body cells—such as skin, muscles, blood, and bones.

Digestion and Absorption of Protein

- **Digestion in the Small Intestine:** The digestion of proteins consumed in food primarily takes place in the small intestine of the body.
- **Production of Amino Acids:** Throughout this complete process of digestion, protein breaks down, resulting in the production of amino acids.
- **Absorption by the Intestine:** All the essential amino acids produced after digestion are absorbed into the body through the blood, being completely absorbed by the intestine.

Types of Proteins

Proteins are classified into various categories based on their requirement, constituent elements, and structure:

(A) On the Basis of Requirement:

- **Non-essential Protein:** These are proteins that the body can synthesize on its own within itself; it is not mandatory to take them from external food sources (e.g., Prothrombin).
- **Essential Protein:** These are proteins that the body cannot synthesize on its own; therefore, it is highly essential to obtain them from external food sources (e.g., milk and egg).

(B) On the Basis of Chemical Composition:

- **1. Simple Protein:** This type of protein is composed solely and exclusively of amino acids.
- **2. Conjugated Protein:** Along with amino acids, some other non-protein elements are also attached to these proteins. These attached external substances are called the **Prosthetic Group**. Its major examples are listed below:
  - **Glycoprotein:** This is formed by the joining together of protein and carbohydrate.
  - **Hemoglobin:** This is formed by the combination of protein and heme (an iron element).
  - **Phosphoprotein:** This is formed by the combining of protein and phosphoric acid, such as **casein protein** found in milk.
  - **Lipoprotein:** This is formed by the combination of protein and fat (Lipid), such as lipovitellin found in egg yolk, and lipoproteins present in the blood.
  - **Other Examples:** Lipo protein and **Opsins** also fall into this same category.
- **3. Derived Protein:** These are proteins that are formed by the denaturation or breakdown of natural simple or conjugated proteins through physical or chemical methods (such as hydrolysis, enzyme action, or heat), for example – proteoses, peptones, peptides, and gelatin, etc.

(C) On the Basis of Structure:

Proteins mainly have 4 types of structures:

- **Primary:** This is a simple linear structure of protein.
- **Secondary:** This is a coiled (Helical) structure of protein.
- **Tertiary:** In nature, the maximum number of proteins are found in this tertiary structure form.
- **Quaternary:** This is the most complex structure of protein, and our **hemoglobin** functions in this complex quaternary structure.

Major Specific Proteins: Their Nature, Function, and Location in the Body

The details of the major specific proteins found in the human body are as follows:

- **Keratin:**
  - **Nature:** This is a fibrous protein.
  - **Main Function:** It works to provide external strength and protection to the body.
  - **Location in the Body & Examples:** It is found in our nails, hair, the outer layer of the skin (epidermis), and horns. It is responsible for the stiffness of hair and the strength of nails.
- **Collagen:**
  - **Nature:** This also falls under the category of a fibrous protein.
  - **Main Function:** It works to give flexibility and strength to the tissues of the body.
  - **Location in the Body & Examples:** It is primarily found in the skin, tendons, ligaments, and cartilage, and it provides elasticity to the skin and strength to the joints.
- **Actin:**
  - **Nature:** This is a contractile protein.
  - **Main Function:** It helps in the contraction of muscles.
  - **Location in the Body & Examples:** It is located in the muscle tissue and forms the thin filament of the muscle fiber.
- **Myosin:**
  - **Nature:** This is also a contractile protein.
  - **Main Function:** It works in conjunction with actin protein to bring about the contraction of muscles.
  - **Location in the Body & Examples:** It is found in the muscle tissue and forms the thick filament of the muscle fiber.

Major sources of protein

- **Generally Good Sources:** Pulses, milk, fish, egg, soybean, and sprouted grains are considered very good sources of protein.
- **Best Plant-Based Sources:** While all plants contain some amount of protein, peanuts, beans, grains (corn and wheat), and pulses are the best plant sources.
- **Animal-Based Sources:** Meat, fish, eggs, milk, and cottage cheese (paneer) are the primary sources of animal protein.
- **Sources with Maximum Content:** The maximum amount of protein is found in **Spirulina (blue-green algae)**, followed by **soybean** in second place.

Main Functions of Protein

- **Growth and Repair:** It is essential for the growth, development, and structure of the body, and helps in the formation of cells, their division, and the repair of wear and tear.
- **Enzymes and Biological Processes:** Proteins play an extremely important role as enzymes in various types of biochemical reactions.
- **Genetic Role:** Proteins play an important role in the development and expression of our genetic traits.

- **Alternative Supply of Energy:** In the absence (deficiency) of fat and carbohydrates, proteins work to provide energy to the body as per requirement.
- **Mental Development:** Along with physical benefits, proteins help in the development of the human body's mental strength.

Diseases Caused by Protein Deficiency

A deficiency of protein in food primarily causes the following serious diseases in children:

1. Kwashiorkor: (RAS 2024)

- **Cause of Deficiency:** This disease is caused solely by a 'deficiency of protein'.
- **Major Symptoms:** The child's stomach swells outward, fat starts accumulating in the body, the liver becomes enlarged (Fatty enlarged liver), and swelling (edema) appears on the body.
- **Affected Age Group:** It primarily affects children from the age of 6 months up to 5 years.
- **Important Fact:** In this disease, the child receives sufficient calories (energy) in their food, but a severe deficiency of protein persists.

2. Marasmus:

- **Cause of Deficiency:** This disease occurs due to a 'simultaneous deficiency of both protein and energy (calories)' in the body.
- **Major Symptoms:** Extreme lean and thinness (wasting) occurs in the child's body, muscles are completely wasted away, and wrinkles appear on the skin.
- **Affected Age Group:** It is primarily seen in infants and young children from 6 months up to 1 year of age.
- **Important Fact:** This disease arises due to the body receiving inadequate food over a long period of time.

3. Celiac Disease:

- **Nature:** This is a serious autoimmune condition.
- **Cause:** This disease is caused by a protein named **Gluten** found in grains like wheat, barley, and rye.
- **Treatment:** The only treatment for this disease is to adopt a completely 'gluten-free diet', which helps the body to heal.
- Cataract occurs due to denaturation and aggregation of proteins present in the natural lens of the eye(RAS 2024)

Chemical Testing and Special Points

- **Chemical Testing of Protein:** To test the presence of protein in any food item, Copper Sulphate and Caustic Soda are added to it. If the color of the food item turns Violet upon mixing these two, it fully indicates the presence of protein.
- **Requirement for Proper Development:** If an appropriate amount of protein is present in our daily diet, the growth and development of the body take place in a proper manner.
- **Special Intake According to Age:** During the childhood and adolescence stages of human life, the body undergoes rapid physical development; therefore, children should consume protein in higher quantities during both of these stages.

Fats / Lipids (RAS 2013)

- **Definition:** Fats are organic compounds found in the cells of the human body that are completely insoluble in water.
- **Mixture of Elements:** Fats are primarily composed of three elements – Carbon (C), Hydrogen (H), and Oxygen (O).
- **Ester Structure:** Chemically, fats are primarily esters of glycerol and fatty acids.
- **Forms Based on Physical State:** Fats are greasy in taste, and they are mainly seen in two forms within the body:
  - **Tallow/Hard Fat:** Fat existing in a solid form in the body is called hard fat.
  - **Oily Fat:** Fat existing in a liquid form in the body is called oily fat.

Energy Storage and Value

- **Hub of Energy:** Fats are called the primary hub of energy for the human body because a massive amount of energy remains stored in the form of fat.
- **Highest Energy Value:** Among all nutrients, the body receives the highest amount of energy from fats. The complete oxidation of 1 gram of fat provides approximately **9 kcal/g** of energy to the body.
- **Comparison with Carbohydrates:** Upon oxidation, fats provide almost double the energy compared to carbohydrates. The primary chemical reason for this is that the amount of oxygen in fat molecules is much lower compared to carbohydrates.

Storage of Fat in the Body

- **Location of Storage:** Excess fat in our body is primarily stored beneath the skin and around the internal organs.
- **Transformation of Excess Energy:** When we consume food in such large quantities that all the energy generated from it cannot be utilized by the body for daily activities, that excess energy accumulates as fat beneath the skin.

Specific Examples of Fat Storage in Nature

- **Camel's Hump:** A very large amount of fat is stored in a camel's hump. When the camel faces a shortage of food, this stored fat becomes the primary source of energy for its body, which is why a camel can survive for many days without eating or drinking.

- Important Fact: Double-humped Bactrian camels are found in Ladakh in our country.

- **Polar Bear:** A thick layer of a large amount of fat accumulates beneath the skin of a polar bear. This fat acts as an energy source for their body and completely helps them survive without eating or drinking during their months-long winter sleep period (**Hibernation**).

Main Functions of Fat

- **Supply of Abundant Energy:** It helps in continuously providing high amounts of energy to the muscles and other parts of the body.
- **Thermal Insulation:** The layer of fat stored under the skin protects the body from cold and conserves heat by preventing internal body heat from escaping out.
- **Protection of Internal Organs:** It forms a protective layer around various delicate internal organs of the body, keeping the organs completely safe from external or mechanical shocks.
- **Formation of Cell Structure:** Apart from providing energy, fat helps in building the structural materials of cells and tissues, such as forming the cell membrane and other cell organelles.
- **Absorption of Vitamins:** Fat is primarily helpful in the absorption of fat-soluble vitamins—such as **Vitamins A, D, E, and K**—into the body.
- **Physical Fitness/Tone:** Fat accumulates under the skin of the body to provide a toned shape to the body and gives strength to the muscles.

Major Sources of Fat

Sources for obtaining fat in food are divided into two main categories:

- **(a) Fat Derived from Plants (Plant Sources):** Mustard, coconut, peanut, sesame, and soybean oil, as well as various types of nuts, are its main examples.
- **(b) Fat Derived from Animals (Animal Sources):** Milk, ghee, butter, paneer, egg (egg yolk), meat, and fish fat are its prominent examples.

Types of Fat

Based on their physical state at room temperature, their sources, and their impact on health, fats are classified into three major categories:

Type of Fat	State at Room Temperature	Major Sources	
Saturated Fat	Solid	Ghee, butter, coconut oil, animal fat	❖ It is a concentrated source of energy. ❖ High consumption can increase **LDL cholesterol** in the body. ❖ Its excessive intake increases the risk of heart diseases (hence, it is required only in limited quantities).
Unsaturated Fat	Liquid	Mustard, peanut, sunflower, olive oil	❖ It is considered a **"good fat"** for health. ❖ It is completely helpful in increasing **HDL cholesterol** in the body. ❖ It is highly beneficial for heart health.
Trans Fat	Semi-solid / Solid	Vanaspati ghee (Dalda), biscuits, cake, fried junk food	❖ It is considered the **most harmful** fat for health. ❖ It increases LDL and decreases good HDL cholesterol in the body. ❖ Its consumption drastically increases the risk of obesity, diabetes, and heart disease.

Types of Unsaturated Fatty Acids

Based on the chemical structure of unsaturated fatty acids and their effects, they are further divided into two categories:

Basis	MUFA (Monounsaturated Fatty Acid)	PUFA (Polyunsaturated Fatty Acid)
Number of Double Bonds	It contains only **one** carbon–carbon double bond (C=C).	It contains **more than one** carbon–carbon double bond.
Effect on Heart	This helps in reducing LDL cholesterol and increasing HDL in the body.	This is considered comparatively more beneficial for human heart health.
Essential Fat	This is generally not mandatory or essential for the body.	This includes fatty acids that are highly **essential** for the body.

Major Examples	Oleic Acid	Omega-3, Omega-6 fatty acids {Flaxseed (Linseed) is the best plant-based source of Alpha-Linolenic Acid (ALA), an essential 18-carbon Omega-3 fatty acid.(RAS 2016)}
Main Sources	Olive oil, peanut oil, mustard oil	Fish oil, flaxseeds, sunflower oil

Key Point:

The Primary Cause of Obesity: Consuming a diet excessively rich in fats causes our body to become shapeless. In contemporary times, children and adolescents consume large quantities of 'junk food'—which contains an extremely high amount of fat (particularly trans fats)—leading to a rapidly rising problem of obesity among them.

VITAMINS

- **First Use of the Word:** The word 'vitamin' was first used by the scientist **Funk**.
- **Literal Meaning:** The word vitamin means **'Vital amines'**, which directly translates to – amines found in living systems.
- **Basic Definition:** In addition to carbohydrates, fats, and proteins, those food substances or organic compounds that are essential for the general health, regular growth, and proper nutrition of the human body are called vitamins.
- **Requirement in Small Quantities:** These are food substances whose very small (minute) quantity is completely beneficial for the growth and development of our body.
- **Lack of Energy:** Vitamins do not provide any kind of energy to the body.
- **Control of Metabolic Activities:** Despite not providing energy, these are bio-organic compounds that control various metabolic activities of the body and smoothly regulate the biological processes of the body.
- **Lack of Synthesis:** The production or synthesis of vitamins does not occur automatically inside the animal body.
- **Obtaining from Diet:** Due to the lack of synthesis in the body, it is highly essential to obtain them through our daily external diet.
- **Status of Discovery:** So far, about **15 vitamins** have been discovered by science, out of which **6 vitamins** are considered majorly prominent.

Impact on Health & Significance

General Functions and Benefits of Vitamins

Vitamins play a primarily beneficial role for the human body in the following ways:

- It is highly essential for the natural and regular growth of the human body.
- They are indispensable for always keeping the entire body disease-free and healthy.
- They make a significant increase in the body's disease-fighting capacity (immunity) and help protect it from various diseases.
- They have a special contribution to keeping human appetite completely normal.
- They prove helpful in keeping the digestive process of the body smooth and organized.
- It plays an important role in keeping the skin of the human body completely healthy.

Classification of Vitamins on the Basis of Solubility

On the basis of solubility, all vitamins are mainly divided into two large groups:

(A) Fat Soluble Vitamins: (RAS 2021/2013)

- **Nature:** These vitamins are primarily oily substances that are completely insoluble in water, but easily dissolve in fats and oils.
- **Examples: Vitamins A, D, E, and K** are prominent examples of such fat-soluble vitamins.
- **Storage in Liver:** Vitamin A and Vitamin D are found and stored in abundance or excess within the liver cells of our body.

(B) Water Soluble Vitamins

- **Nature:** These vitamins are completely soluble (dissolvable) in water.
- **Examples:** This category mainly includes **Vitamin B Complex** and **Vitamin C**.
- **Low Storage:** The storage of these types of water-soluble vitamins in the body's cells occurs in very minute quantities.

Specific Epithets of Major Vitamins

Based on their specific biological functions, various vitamins are known by the following special epithets:

- **Vitamin A:** Anti-infective vitamin
- **Vitamin D:** Sunshine vitamin
- **Vitamin E:** Anti-sterility vitamin
- **Vitamin K:** Coagulation vitamin
- **Vitamin C:** Anti-scurvy vitamin (written as Anti-curvy vitamin)

Major Vitamins: Scientific Name, Source, Function

1. Vitamin A (Retinol)

- **Scientific Name & Epithet:** Its scientific name is Retinol, and it is also called the 'Anti-infection vitamin'.
- **Main Sources:** It is primarily found in milk, egg, fish, and green and yellow vegetables.
- **Function:** It is highly essential for eye eyesight. Within our liver, beta-carotene gets converted into this Vitamin A.
- **Deficiency Disease:** Its deficiency leads to night blindness, a decrease in the body's immunity (disease-fighting capacity), dry eyes, and a disease named xerophthalmia.

2. Vitamin B-1 (Thiamine)

- **Main Sources:** It is obtained from green vegetables, milk, yeast, and whole grains.
- **Function:** It helps in the smooth functioning of the body's nervous system.
- **Deficiency Disease:** Its deficiency causes the famous disease named Beri-Beri in the body.
- **Special Note:** Excessive consumption of polished rice leads to a deficiency of Vitamin B-1 in the body, which increases the risk of contracting Beri-Beri disease.

3. Vitamin B-2 (Riboflavin)

- **Main Sources:** Its primary sources include green vegetables, milk, and yeast.
- **Function:** It is majorly responsible for the natural physical growth of the human body.
- **Deficiency Disease:** Its deficiency causes mouth ulcers, cracking at the corners of the lips (which is called 'Cheilosis'), and problems like dermatitis.

4. Vitamin B-3 (Niacin / Nicotinic Acid)

- **Main Sources:** It is primarily found in yeast, milk, tomato, and green leafy vegetables.
- **Function:** It plays an important role in various metabolic activities occurring inside the body.
- **Deficiency Disease:** Its deficiency causes Pellagra disease, which is also called **'3D disease'**. This 3D refers to Diarrhoea, Dermatitis, and Dementia.

5. Vitamin B-5 (Pantothenic acid)

- **Main Sources:** Whole grains, pulses, eggs, mushrooms, avocados, and various green vegetables are considered its best sources.
- **Deficiency Disease:** Its deficiency in food causes severe burning or tingling sensations in the hands and feet, which is called **'Burning feet syndrome'** in medical science.

6. Vitamin B-6 (Pyridoxine)

- **Main Sources:** Its primary sources include grains, pulses, eggs, and meat.
- **Function:** It works to keep the blood circulation smooth inside the body.
- **Deficiency Disease:** Its deficiency causes **Microcytic or Sideroblastic Anaemia** disease, and muscle cramps (Cramps) start occurring in the body.

7. Vitamin B-9 (Folic Acid)

- **Main Sources:** It is found in abundance in green leafy vegetables (such as spinach, fenugreek), pulses, beans, citrus fruits (such as orange, mosambi), sprouted grains, peanuts, and dry fruits.
- **Deficiency Disease & Impact:** Its deficiency causes anemia (lack of blood), extreme fatigue, weakness, and a decreased appetite in the body. Along with this, swelling or a burning sensation in the tongue can occur. A deficiency in women during pregnancy can cause serious problems in the development of the unborn baby's nervous system.

8. Vitamin B-12 (Cyanocobalamin)

- **Main Sources:** It is primarily obtained from fish and other animal food products, etc.
- **Function:** It regulates various metabolic (Metabolism) activities of the body.
- **Deficiency Disease:** Its deficiency causes **Pernicious Anaemia** disease in the body, and the person experiences problems like anxiety/nervousness.

9. Vitamin H / B-7 (Biotin)

- **Main Sources:** Its primary sources include milk, yeast, and eggs.
- **Function:** It also takes part in managing the normal metabolic activities of the body.
- **Deficiency Disease:** Its deficiency can lead to serious conditions such as excessive hair loss from the head, skin inflammation (swelling of the skin), and paralysis.

10. Vitamin C (Ascorbic Acid)

- **Scientific Name & Epithet:** Its scientific name is Ascorbic Acid, and it is called the 'Anti-scurvy vitamin'.
- **Main Sources:** It is primarily obtained from sour/citrus fruits like lemon, orange, tomato, amla, and guava.
- **Function:** This vitamin performs its primary function by quickly healing injuries or wounds sustained by the body.
- **Deficiency Disease:** Its deficiency leads to bleeding gums and a disease named Scurvy.

11. Vitamin D (Calciferol)

- **Scientific Name & Epithet:** Its scientific name is Calciferol, and it is also called the **'Sunshine vitamin'** because it is obtained from sunlight.

- **Main Sources:** It is obtained from sunlight (sun exposure), oil, butter, eggs, and meat.
- **Function:** It performs the primary function of metabolizing and absorbing Calcium (Ca) and Phosphorus (P) in the body, which makes the bones strong.
- **Deficiency Disease:** Its deficiency causes dry disease or rickets in children, and in adults, the bones become weak and hollow, which is called osteomalacia.

12. Vitamin E (Tocopherol)

- **Scientific Name & Epithet:** Its scientific name is Tocopherol, and it is called the **'Anti-sterility vitamin'** because it is linked to reproductive capacity.
- **Main Sources:** It is primarily obtained from plant oils and soybean, etc.
- **Function:** It acts as an excellent antioxidant in the body, protecting cells from destruction.
- **Deficiency Disease:** Its deficiency leads to a severe decline in human fertility, the body can become a victim of malnutrition, and deformity in muscles (**Muscular dystrophy**) arises.

13. Vitamin K (Phylloquinone)

- **Scientific Name & Epithet:** Its scientific name is Phylloquinone, and it is also called the **'Coagulation vitamin'** due to its blood-clotting property.
- **Main Sources:** It is primarily obtained from green leafy vegetables and various types of pulses.
- **Function:** It performs the primary function of synthesizing **'Prothrombin'**, which is essential for the process of blood clotting in the body.
- **Deficiency Disease:** In the event of a deficiency of this vitamin in the body, blood does not clot upon injury, which poses a risk of excessive bleeding.

Minerals

- **Definition:** To ensure the physical structure, proper growth, and complete development of the human body, it is extremely essential to consume a specific quantity of minerals daily in our food.
- **Termed as Minerals:** Our body requires several metals and salts such as iron (Fe), zinc (Zn), iodine (I), salt (NaCl), and calcium phosphate for various chemical reactions, which are collectively known as minerals.
- **Number of Minerals:** The total number of minerals found in our human body is approximately **24**, but among these, certain minerals are considered highly useful for the body.
- **Main Useful Minerals:** For the smooth functioning of the body, minerals like calcium, magnesium, phosphorus, iron, copper, and potassium fall into the category of the most essential minerals.
- **Excretion via Sweat (Sodium Chloride):** During summer days, excessive sweating often leaves white stains on human clothes; these white stains are primarily **sodium chloride (NaCl)**, i.e., common salt, which is excreted from the body.

Detailed Description of Major Mineral Elements: Source, Function, and Deficiency Disease

(A) Iron (Fe)

- **Major Sources:** It is found in abundance primarily in liver, kidney, eggs, meat, blood, pearl millet (bajra), finger millet (ragi), curd, green vegetables, carrots, and jaggery.
- **Main Functions:** It is absolutely essential for the **formation of the protein hemoglobin** within the blood.
  - This hemoglobin performs the primary task of transporting oxygen to all the tissues of our body.
  - It is entirely instrumental in the **process of oxidation** occurring within the cells and tissues of the body.
- **Deficiency Disease / Impact:** A deficiency of iron in the body leads to a disease called **Anemia (lack of blood)**, resulting in persistent and extreme weakness in the body.

(B) Iodine (RAS 2024)

- **Major Sources:** It is obtained from common salt, seafood, green leafy vegetables, salts, aquatic fish, jamun, and black salt.
- **Main Functions:** This is an extremely essential mineral in a very small (minute) quantity for the **formation of thyroxine hormone** secreted by the thyroid gland located in our throat.
- **Deficiency Disease / Impact:** Its deficiency in food causes the famous disease named **Goitre** and the body becomes a victim of **Hypothyroidism**.

(C) Calcium

- **Major Sources:** Its most prominent sources include milk, eggs, and various green vegetables.
- **Main Functions:** Calcium salts work together with Vitamin D to provide firmness and strength to the **bones and teeth** in our body.
  - It is necessary for regulating the natural **contraction** process of muscles.
  - It plays an indispensable role in the process of **blood clotting / coagulation** when the body gets injured.
- **Deficiency Disease / Impact:** Its deficiency causes dry disease, i.e., **Rickets**, in children, and in adults, the bones become weak and hollow, which is called **Osteoporosis**.

(D) Phosphorus

- **Major Sources:** It is found in milk, green vegetables, pearl millet (bajra), finger millet (ragi), dry fruits, liver, and kidney.
- **Main Functions:** This mineral works together with calcium to chemically make the bones and teeth firm and strong.
- **Deficiency Disease / Impact:** Due to a deficiency of phosphorus in food, the **bones and teeth become weak** in the human body.

(E) Sodium

- **Major Sources:** It is obtained in abundance from common salt, fish, meat, eggs, and milk.
- **Main Functions:** It primarily helps in regulating the **osmotic balance** of cells and tissue fluids in the body.
  - It helps in the smooth functioning of our **nervous system** and in **nerve impulse transmission**.
  - It is necessary for maintaining muscle contraction and the electrolyte balance of the body.
- **Deficiency Disease / Impact:** Its deficiency leads to acute **cramps** in the muscles and gives rise to various disorders associated with the nervous system.

(F) Potassium

- **Major Sources:** It is present in sufficient quantities in practically almost all food products.
- **Main Functions:** It is essential for maintaining osmotic balance by working together with sodium in cells and tissue fluids.
  - It is considered an extremely essential mineral for the rapid transmission of nerve impulses.
  - It takes part in the contraction of muscles, the electrolyte balance of the body, and the successful management of various cellular activities.
- **Deficiency Disease / Impact:** A deficiency of this in the body causes severe weakness in the muscles and makes the heartbeat irregular.

(G) Cobalt

- **Main Functions:** It is a major structural component of Vitamin B-12, which is essential for our body, and it significantly helps in the formation of red blood cells, i.e., RBC synthesis.
- **Deficiency Disease / Impact:** A deficiency of cobalt leads to a deficiency of Vitamin B-12 in the body, due to which a person becomes a victim of a serious disease named Megaloblastic Anaemia.

(H) Selenium

- **Main Functions:** It acts as an excellent antioxidant for the protection of cells inside the human body.
- **Deficiency Disease / Impact:** Its deficiency weakens the body's immune system and drastically increases the probability of heart disease.

(I) Zinc

- **Main Functions:** It takes part in the formation of various crucial enzymes inside the body and primarily provides assistance in antioxidant activities occurring in the body.
- **Deficiency Disease / Impact:** Due to a deficiency of zinc, the natural growth of the body stops, wounds sustained on the body heal very late, and the disease-fighting immunity significantly decreases.

Significance of Other Trace Minerals

- **Control of Crucial Reactions:** In addition to phosphorus and zinc, numerous compounds of chlorine, copper, and magnesium are also highly essential for controlling various crucial biochemical reactions occurring in our body.
- **General Health:** All these trace elements are considered completely indispensable for maintaining the general health of humans and for the continuous growth of the body.

Water

- **Indispensable Component:** Water is an extremely essential, indispensable, and life-giving component for the human body.
- **Chemical Composition:** Water is mainly composed of a fixed ratio of two gases – Hydrogen (H2) and Oxygen (O2).
- **Total Percentage of Water in the Human Body:** Approximately 70% of the human body is completely made up of water.

Main Biological Functions of Water

- **As a Universal Solvent:** Water acts as an excellent solvent inside the body, in which various types of minerals, salts, and nutrients easily dissolve.
- **Medium for Biochemical Reactions:** Water provides an indispensable medium for the successful execution of all essential biochemical reactions taking place inside the body.
- **Regulation and Control of Temperature:** Water plays the most crucial role in keeping the internal temperature of the body completely balanced, regulated, and controlled.
- **Excretion of Harmful Substances:** Water continuously helps in excreting various toxic and harmful waste products, generated during the body's metabolic activities, out of the body in the form of urine and sweat.
- **Protection from Diseases:** By maintaining internal cleanliness and controlling the temperature, water indirectly protects us from many types of serious diseases.

Percentage of Water in Different Organs and Components of the Body

The amount of water varies completely across different organs, tissues, and fluids of the human body, the details of which are as follows:

- **Amount of Water in Liver:** Approximately 69% water is present in our liver.
- **Amount of Water in Muscles:** Approximately 75% of the human muscle consists of water.
- **Amount of Water in Whole Blood:** If we consider the entire human blood, about 79% to 82% water is found in it.
- **Amount of Water in Blood Plasma:** In the liquid part of blood, which is called plasma, about 90% to 92% consists of water alone.

Special Knowledge and Daily Requirement

- **Daily Requirement of Water:** To carry out all the biological processes of the human body in a healthy manner, it is highly essential for us to drink 2 to 3 liters of water daily.
- **Abundant Example of Water in Plants:** Water is also found in high amounts in fruits and vegetables; for example, up to approximately 95% of watermelon consists of water alone.

Dietary Fibres / Roughage

- **Basic Definition:** Fibrous substances called cellulose are found in whole grains, fruits, and various green vegetables, which we consume as food.
- **Termed as Roughage:** These essential dietary fibres present in food are primarily called **"Roughage"** or fibre.
- **Indigestible Component:** Dietary fibre is a component of human food that is completely indigestible (cannot be digested) inside the body.
- **Basic Composition:** Chemically, all types of dietary fibres are primarily made of **Cellulose**.

Main Biological Functions of Dietary Fibres or Roughage

To keep our body disease-free and active, these dietary fibres perform the following highly important functions:

- **Keeping Digestion Smooth:** This roughage primarily helps in the successful digestion of food substances in our body and keeps the entire digestive process smooth.
- **Complete Prevention of Constipation:** The adequate presence of fibres in food completely protects the human body from the problem of constipation.
- **Motility of Intestines:** Dietary fibre increases the natural movement of the intestine (bowel), which keeps the food transit system healthy.
- **Prevention of Sticking to Intestines:** Due to the presence of roughage, the consumed food does not stick to the inner layers of our intestines.
- **Absorption of Toxic Substances and Excess Water:** Whatever harmful or toxic substances and excess water are produced in the body during the complex process of digestion, roughage completely absorbs or soaks up all those toxic elements.
- **Control over Blood Sugar and Diabetes:** These fibres absorb glucose slowly in the body. As a result, the sugar level in the blood always remains completely controlled, and the risk of a person developing diabetes is significantly reduced.

Major Sources of Dietary Fibre

Roughage or fiber is primarily found in abundance in the following food items:

- **Grains & Pulses:** Grains, pulses, bran, corn, and kidney beans are excellent examples of this.
- **Vegetables:** Vegetables, beans, broccoli, cabbage, cauliflower, carrots, radish, spinach, ladyfinger (okra), peas, and cucumber are rich sources of fiber.
- **Fruits:** Various types of fruits such as apples, pears, and guavas are full of fiber.
- **Other Food Items:** Salad, broken wheat (daliya), dry fruits, peanuts, flour containing bran, brown rice, and oats are also considered very good sources of fiber.
- **Selection of Grains:** We should primarily include grains rich in high fiber in our daily diet, such as corn, kidney beans, and various pulses.
- **Right Way to Eat Fruits:** Health-promoting fruits like apples, pears, and guavas should always be eaten with their skin/peel, because a very high amount of fiber is present in their peels.
- **Abundant Intake of Vegetables:** The amount of fiber is found to be quite high in radish, cabbage, peas, and cucumber etc., therefore, their regular consumption is highly essential for health.
- **Dietary Changes:** While cooking, instead of refined flour (maida) separated by sieving, one should always use natural flour containing bran.
- **Supplements and Alternative Grains:** To keep the body disease-free, consuming brown rice and oats instead of regular white rice is highly beneficial for health.

Balanced Diet

S.No.	Food Component / Nutrient	Daily Required Quantity	Main Role / Function	Amount of Energy (kcal/g)	Best Source
1.	**Carbohydrate**	130 to 150/ gram	Main and primary fuel of the body (Fast Energy)	approx 4	Rice, roti, potato, sweet potato, banana, fruit, oats
2.	**Protein**	78/gram	Muscle repair and energy when needed	approx 4	Pulses, milk, egg, fish, chicken, curd, beans
3.	**Fats**	22 / gram	Concentrated source of energy and storage (Long-term Energy)	approx 9	Ghee, butter, oil, nuts (almonds, cashews), avocado, seeds
4.	**Vitamin**	As per requirement	Regulation and protection of biochemical reactions and metabolism	—	Green vegetables, fruits, milk, egg, sunlight
5.	**Minerals**	660/milli gram	Strengthening of bones & teeth, osmotic balance, and hormone formation	—	Milk, green vegetables, bajra, ragi, salt, liver
6.	**Water**	2-3 / liter as per requirement	Function of solvent, temperature control, and excretion of wastes	—	Drinking water, watermelon, liquid substances
7.	**Dietary Fibre (Fiber)**	As per requirement	Keeping digestion smooth, prevention of constipation, and blood sugar control	—	Grains with bran, fruit, vegetables, pulses, daliya

10 Environment & Ecology

BASIC DEFINITIONS

Environment

- System constituting the **interaction of biotic and abiotic factors** to shape the habitat and ecosystem of an organism.
- Constitutes **physical** (water, air), **biological** (biomolecules), and **chemical interactions** (chemical cycles) that affect an organism or a group of organisms.
- All organisms depend on the environment to carry out their natural life processes and meet their physical requirements (food, energy, water, oxygen, shelter, etc.).

Ecology

- The term "ecology" was coined by the German zoologist, Ernst Haeckel, in 1866.
- Branch of biology dealing with the study of relations of organisms to one another (energy flow and mineral cycling) and their physical surroundings (environment).
- Studies individuals, organisms, populations, communities, ecosystems, biomes, and biospheres (various levels of ecological organisation).

PRINCIPLES OF ECOLOGY

Adaptation	Appearance/behaviour/structure/mode of life of an organism that allows it to **survive in a particular environment**. Types: - **Morphological** e.g., the Fennec fox living in the desert has large ears (allows heat radiation from the body to allow its cooling); mammals from colder climates generally have shorter ears and limbs to minimise heat loss. (This is called **Allen's Rule**.) - **Physiological** e.g., venomous animals produce poison to catch their prey, to protect themselves or to ward off predators - **Behavioural** - Hibernation as a winter survival technique. E.g., the phenomenon of hibernation observed in bats, bears and rodents.
Variation	- It refers to differences in genetic or physical traits among individuals within a population, including variations in genes and their combinations. - Mutations, changes in climate, geographical barriers etc., induce variations over a period of time.
Speciation	- Process of **formation of new species.** - A species comprises many populations. Often, different populations remain isolated due to geographic barriers. - Over a period, geographic isolation leads to speciation, i.e., **geographic speciation or allopatric speciation**. - **Sympatric speciation:** New species develop spontaneously (maybe due to different food sources) despite no **physical barriers** to inter-breeding.
Mutation	- **Changes in genetic material** that result from an error in DNA replication, causing the **rise of new genes**. - As a result, members of the same species show 'variation' and are not identical.
Natural Selection	- Proposed by **Darwin** and **Wallace**, it is a process by which species adapt to their environment. - An **evolutionary force** that selects among variations, i.e. genes that help the organism to have better chances of surviving, reaching reproductive age and passing on suitable adaptations to their progeny.

Evolution	❖ **The process by which living organisms change over time through changes in the genome.** ❖ May give rise to new species and make the organism better suitable for the present environment through natural selection, variation etc. ❖ **Charles Darwin** and **Alfred Wallace: Theory of Evolution** in **1859**. This theory has been extended in light of progress in genetics and is known as **Neo-Darwinism**.
Extinction	❖ The **complete disappearance** of a species from Earth primarily due to environmental changes, biological competition or inability to evolve fast enough to cope with the changing environment. ❖ Currently, the **6th Mass Extinction (Anthropogenic Extinction – human-induced)** is in progress, exacerbated by mankind's over-exploitation/misuse of natural resources, fragmentation/loss of natural habitats, destruction of ecosystems, pollution, and global climate change.

Notable Extinct Species and their Causes of Extinction

Here's a table of species that went extinct along with the reasons behind their extinction and the timeline:

Species	Extinction Year	Habitat	Cause of Extinction
Dodo	1681	Mauritius (forests)	Overhunting by humans and predation by introduced species (e.g., rats, pigs)
Passenger Pigeon	1914	North America (forests)	Mass hunting and habitat destruction due to deforestation
Tasmanian Tiger (Thylacine)	1936	Tasmania (grasslands, forests)	Hunting by humans, habitat loss, and competition with introduced species like dogs
Baiji (Yangtze River Dolphin)	2006 (functionally extinct)	Yangtze River, China	Habitat degradation due to dam construction, pollution, and overfishing
Great Auk	1844	North Atlantic Ocean	Overhunting for feathers, meat, and eggs; habitat exploitation by humans
Pyrenean Ibex	2000	Pyrenees Mountains, Spain	Overhunting, habitat loss, and competition with domestic livestock
Steller's Sea Cow	1768	North Pacific (coastal waters)	Overhunting for meat and fat by humans shortly after its discovery
Caribbean Monk Seal	1952	Caribbean Sea	Overhunting and habitat degradation due to human activities
Golden Toad	1989	Costa Rica (cloud forests)	Climate change, habitat loss, and fungal infections (chytridiomycosis)
Pinta Island Tortoise	2012 (death of "Lonesome George")	Galápagos Islands	Habitat destruction, hunting, and predation by introduced species (e.g., goats, rats)

Species Showing Hibernation

Category	Species	Notable Features
Mammals	Bears (e.g., Black Bear, Grizzly Bear)	Slight decrease in body temperature; metabolic rate slows significantly.
	Bats (e.g., Little Brown Bat, Big Brown Bat)	Enter torpor; conserve energy during food-scarce winters.
	Ground Squirrels (e.g., Arctic Ground Squirrel)	Body temperature drops to near-freezing levels.
	Hedgehogs (e.g., European Hedgehog)	Heart rate and body temperature drop significantly.
	Marsupials (e.g., Mountain Pygmy Possum)	Hibernate for months in alpine regions of Australia.

Reptiles	Turtles (e.g., Painted Turtle)	Hibernate underwater, relying on anaerobic metabolism.
	Snakes (e.g., Garter Snake)	Gather in communal dens to hibernate.
	Lizards (e.g., Green Iguana)	Hibernate in burrows during cold conditions.
Amphibians	Frogs (e.g., Wood Frog, Bullfrog)	Produce antifreeze-like substances to survive freezing.
	Salamanders (e.g., Spotted Salamander)	Hibernate underground or in aquatic environments.
Fish	Carp (e.g., Common Carp)	Hibernate at the bottom of water bodies with reduced activity.
	Catfish (e.g., Channel Catfish)	Metabolism slows down during colder months. The **suckermouth catfish, or pleco**, showcases extraordinary survival by enduring months in dried mud without water. Equipped with specialized breathing organs, it enters dormancy, akin to hibernation, until rain rehydrates its environment.
Insects	Ladybugs	Cluster in sheltered places for warmth during hibernation.
	Bees (e.g., Bumblebee)	Queen bumblebees hibernate during winter.
	Butterflies (e.g., Mourning Cloak)	Hibernate in tree hollows or cracks.
Birds	Common Poorwill (Phalaenoptilus nuttallii)	Only bird known to hibernate for extended periods; enters a torpor-like state.

Ecological Hierarchy

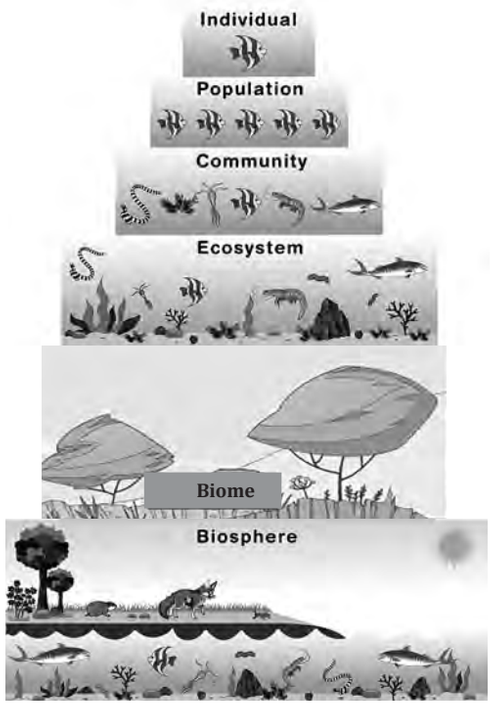


Fig. 10.1: Ecological Hierarchy

Individual and Species	❖ **Individual:** An organism that can act or function independently. ❖ **Species:** A group of living organisms consisting of similar individuals capable of exchanging genes (interbreeding). e.g., Homo sapiens. ❖ Basic unit of taxonomy
Population	❖ Community of interbreeding organisms (same species) occupying a defined area during a specific time.

Community	❖ Named after the dominant plant form. Eg:, a grassland community is dominated by grasses, though it may contain herbs, trees, etc. ❖ **Major Communities:** Large-sized and relatively independent. They depend only on the Sun's energy from outside. E.g., Tropical evergreen forests. ❖ **Minor Communities:** Depend on neighbouring communities and are often called societies. They are secondary aggregations within a major community. E.g., a mat of lichen on a cow dung pad. ❖ **Stable Community:** Does not show much variation in productivity from year to year. It is resilient to occasional disturbances (natural or human-made) and invasions by alien species.
Ecosystem	❖ The **structural and functional unit of ecology** where the living organisms interact with each other and the surrounding environment
Biome	❖ A large geographical area of distinctive plant and animal groups that are adapted to that particular environment. ❖ **Five Major Types of Biomes: Aquatic**, **Grassland**, **Forest**, **Desert**, and **Tundra**. ❖ Biomes are distinct from habitats; a biome **can comprise a variety of habitats**. ❖ Plants and animals in a biome have common characteristics due to similar climates and can be found on various continents. ➢ Eg: **taiga forests** are found beyond the temperate regions of all the continents in the northern hemisphere.
Biosphere	The region on, above, and below the Earth's surface where life exists. ❖ The biological components (supporting life) of the Earth include the **lithosphere**, **hydrosphere** and **atmosphere** (all living organisms and dead organic matter produced by them). ❖ **Absent at extremes** of the North and South poles, the highest mountains, and the deepest oceans (hostile conditions). Occasionally, spores of fungi and bacteria do occur at a great height beyond 8,000 metres, but they are metabolically inactive (dormant life.)

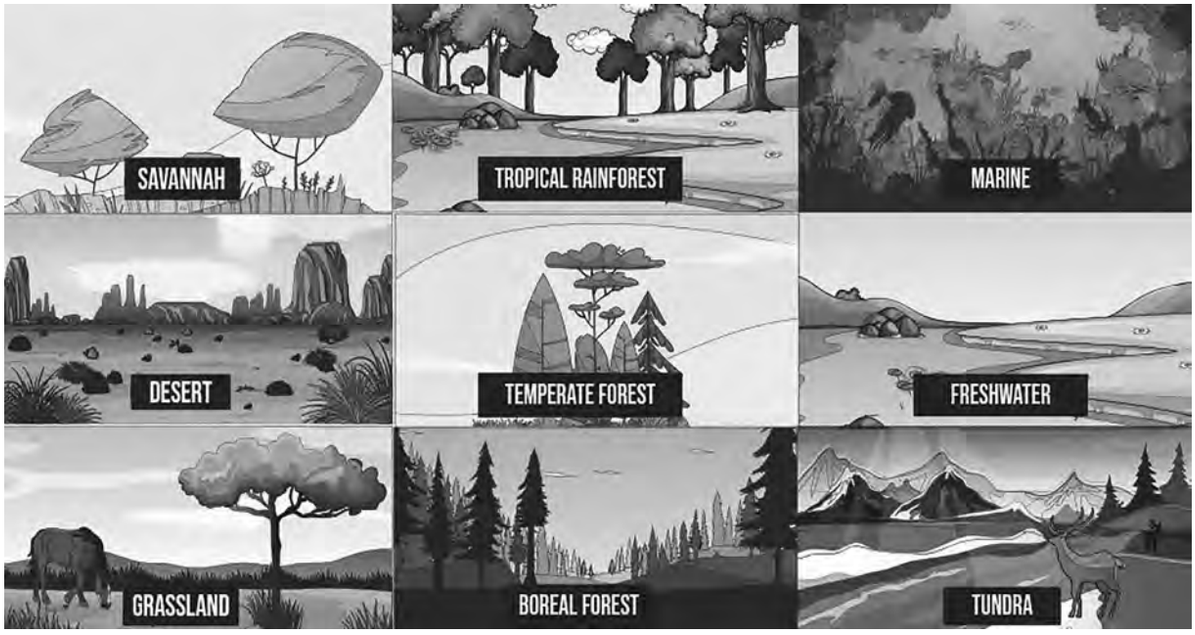


Fig. 10.2: Types of Biomes

ECOLOGICAL NICHE

- **Unique functional role and position** of a species in its habitat or ecosystem
- **No two species in a habitat can have the same niche** because of competition with one another until one is displaced.
- **Components of a Niche:**
  - **Habitat:** The physical environment where the species lives.
  - **Resources:** The food, water, and nutrients the species consumes.
  - **Interactions:** Relationships with other species, such as competition, predation, or mutualism.
  - **Role in Ecosystem:** The ecological functions the species performs, like pollination or seed dispersal.
- Niche knowledge plays an essential role in the conservation of organisms.
  - **Mangroves** occupy a niche in saline intertidal zones, stabilizing coastlines and supporting aquatic biodiversity.
  - **Bees** perform the critical role of pollination, essential for plant reproduction.
- **Types of Ecological Niches:**
  - **Fundamental Niche:** The full range of environmental conditions and resources a species can theoretically use in the absence of competition.
  - **Realized Niche:** The actual conditions and resources a species uses, often narrower due to competition and other biotic interactions.
- **How Niche Influences Extinction?**

Factor	Explanation	Example
Specialized Niche	Species with specialized niches are highly adapted to specific conditions and resources.	The **Giant Panda,** reliant on bamboo, faces extinction risks if bamboo forests are depleted.
Competition	When multiple species compete for the same niche, weaker competitors may be outcompeted and decline.	The **Red Squirrel** in the UK has declined due to competition with the invasive **Grey Squirrel.**
Habitat Loss	Destruction of a species' habitat can render its niche uninhabitable.	The **Bengal Florican**, a grassland bird, faces risk of extinction due to the loss of grassland habitats.
Climate Change	Alterations in temperature, rainfall, and ecosystems may disrupt a species' niche.	The **Polar Bear** is threatened by shrinking Arctic ice, reducing its hunting grounds.

Examples of Niche Adaptation by Organisms to Escape Extinction

Organisms adapt their niches to changing environmental conditions or competition to avoid extinction. These adaptations can be behavioral, structural, or ecological. Here are some notable examples:

Organism	Original Niche	Adaptation	Outcome
Peppered Moth (Biston betularia)	Light-colored moths blending with lichen-covered trees.	During the Industrial Revolution in England, dark-colored moths became dominant to blend with soot-covered trees.	The population survived heavy predation by adapting coloration to match their new environment.
Galápagos Finches	Original seed-eating finches with uniform beaks.	Diversified beak shapes and sizes to specialize in different food sources (e.g., seeds, insects, cactus).	Avoided competition by occupying unique feeding niches, leading to adaptive radiation.
Coral Species	Warm, shallow water in tropical seas.	Some corals adapted to tolerate slightly warmer temperatures and increased acidity in oceans.	Partial survival of coral reefs amidst climate-induced bleaching events.
Polar Bears	Ice-dependent hunting of seals.	Increasing land-based scavenging (e.g., eating bird eggs, berries) as ice melts.	Temporary survival strategy, though long-term effects are uncertain.

Coyotes (Canis latrans)	Plains and grasslands of North America.	Adapted to urban and suburban environments by exploiting human food waste and smaller prey.	Population expansion into areas dominated by human development.
Cichlid Fish	Different depths and food preferences in African lakes.	Specialized feeding strategies such as eating algae, plankton, or snails to avoid competition.	High biodiversity in lakes like Lake Victoria through niche differentiation.
Kangaroo Rats	Arid desert regions in North America.	Developed efficient water retention and nocturnal habits to avoid predators and dehydration.	Survival in extremely dry environments by minimizing water loss.
Hummingbirds	Feeding on general nectar sources in forests.	Specialized beak shapes to access specific flowers, reducing competition with other birds.	Co-evolved with specific plants, ensuring mutual survival.

Habitat

- **Physical environment in which an organism lives**. Multiple organisms may share a common habitat, depending on common requirements.
- **Multiple habitats together make up the environment**.
- **All habitats constitute environments, whereas not all environments are habitats**.

ECOTONE, ECOCLINE, AND EDGE EFFECT

Ecotone

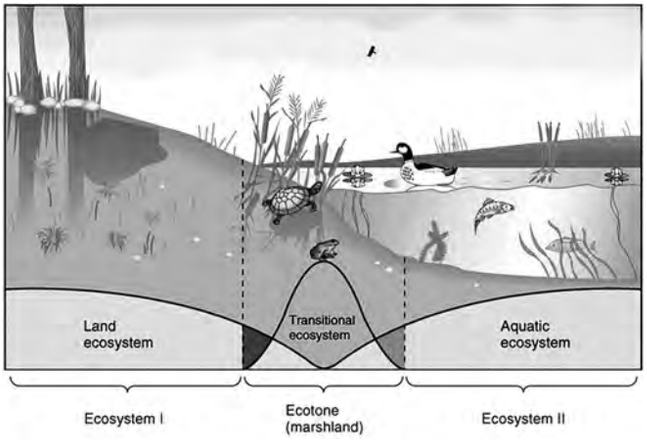


Fig. 10.3: Ecotone

- **Zone of transition** between two biomes where **two communities meet and integrate** (diverse ecosystems). It has characteristics of both ecosystems. **Eg: mangrove forests** (between marine and terrestrial ecosystems); **grassland** (between forest and desert).
- May be **narrow** (between grassland and forest) or **wide** (between forest and desert).
- **Zone of tension:** conditions intermediate to the adjacent ecosystems.
- **Far greater productivity than natural ecosystems** due to wide-ranging species from the adjacent ecosystems being present in the ecotone.
- Well-developed ecotone **may contain some organisms entirely different** from those of the adjoining communities.

Ecocline

- Zone of gradual but continuous change from one ecosystem to another.
- No sharp boundary between the two in terms of species composition. It occurs across the environmental gradient (gradual change in abiotic factors such as altitude, temperature, salinity , depth, etc.)

Edge Effect and Edge Species

- The appearance of diverse ecological characteristics, a high number of species and population density in the ecotone compared to either community is termed the **edge effect.**
- The species that occur primarily or most abundantly in this zone are known as **edge species.**
- **Eg:** In terrestrial ecosystems, the edge effect is especially applicable to birds. The density of birds is greater in the ecotone between the forest and the desert.

ECOSYSTEM

- Functional unit of nature, where living organisms interact among themselves and with the surrounding physical environment in which they live, such that energy is exchanged and system-level processes, such as the cycling of elements, emerge.

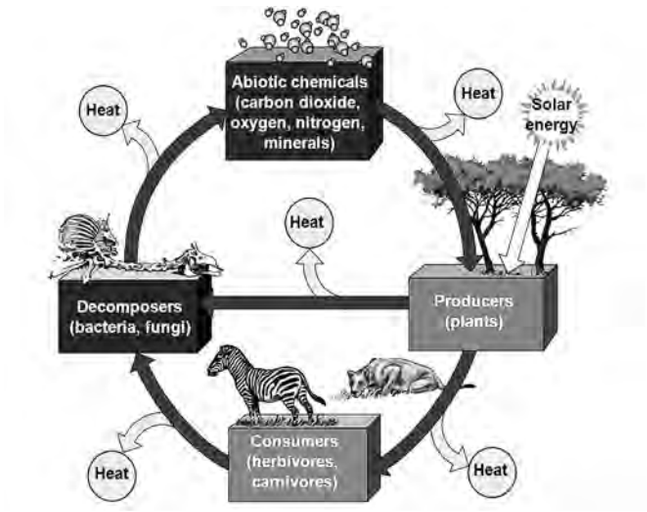


Fig. 10.4: Ecosystem

- All ecosystems are environments, but not vice versa.
- The ecosystem has two components: Biotic and Abiotic.

Biotic Components (RAS 2013)

Biotic components refer to the living organisms in an ecosystem that interact with each other and their environment. These include producers, consumers, and decomposers, playing distinct roles in maintaining ecological balance.

- **Primary Producers/Autotrophs**
  - Organisms that synthesize their own food using sunlight and inorganic substances.
  - **Examples:** Green plants, certain bacteria, cyanobacteria, diatoms , and microscopic algae in aquatic ecosystems.
- **Consumers / Heterotrophs:** Organisms that rely on other organisms for food.
  - **Macro Consumers:**
    - **Herbivores:** Feed on plants. (*e.g., sheep, rabbit*)
    - **Secondary Consumers:** Feed on herbivores. (*e.g., wolves, dogs*)
    - **Tertiary Consumers:** Carnivores feeding on secondary consumers. (*e.g., lions*)
    - **Omnivores:** Feed on both plants and animals. (*e.g., humans, bears*)
  - **Micro Consumers:**
    - **Phagotrophs**: Ingest organic matter.
    - **Osmotrophs:** Absorb dissolved nutrients.
    - **Saprotrophs / Decomposers:** Feed on dead organic material. (*e.g., fungi, bacteria*)
    - **Detritivores:** Consume detritus and help in decomposition. (*e.g., earthworms*)

Abiotic Components

Abiotic components are the non-living physical and chemical elements in an ecosystem that influence living organisms. They form the foundation for the functioning of ecosystems by providing essential resources and conditions for life**.** Eg: air, water, soil, minerals, sunlight, temperature, nutrients, wind, altitude, turbidity, etc

Abiotic Components and Their Effects on Terrestrial Autotrophs

Abiotic Component	Effects on Terrestrial Autotrophs
Light	❖ High intensity favors root growth, shortens stems, and results in smaller, thicker leaves. ❖ Low-intensity light retards growth, flowering, and fruiting. ❖ Only red and blue light are effective in photosynthesis. ❖ Blue light: Plants are small ❖ UV light: Causes dwarfing ❖ Red light: Leads to elongated, etiolated plants.
Temperature	❖ High temperatures cause coagulation of protoplasmic proteins, desiccation of tissues, and moisture depletion. ❖ Low temperatures and frost freeze soil moisture, increase transpiration, and dehydrate cells, leading to canker formation.
Snow	❖ Shortens vegetative growth periods. ❖ Acts as a blanket to protect seedlings from extreme cold and frost.
Nitrogen	❖ Nitrogen is a limiting nutrient due to competition between plants and microbes for soil nitrogen.
Water	❖ Essential for physiological processes, influences distribution, and supports nutrient uptake.
Soil	❖ Provides nutrients, water, and anchorage for plant roots.

pH Levels	❖ Determines soil and water acidity or alkalinity, affecting plant and microbial growth.
Minerals	❖ Vital for plant development and biological functions.
Wind	❖ Influences seed dispersal, transpiration rates, and temperature regulation.
Precipitation	❖ Determines water availability, affecting plant growth and ecosystem productivity.
Dieback	❖ It is the progressive dying, usually backward from the tip of any portion of the plant (adaptive mechanisms to avoid adverse conditions like drought). Generally, the root ❖ remains alive for years together, but the shoots die. E.g. sal, red sanders, silk-cotton tree etc.

FUNCTIONS OF AN ECOSYSTEM

The ecosystem's function is expansive and encompasses a dynamic system that can be explored through the following three aspects

- ❖ Ecological Succession
- ❖ Energy Flow
- ❖ Biogeochemical cycles (Nutrient Cycling)

Ecological Succession

The process where plant and animal communities in an area change over time due to large-scale changes or destruction. Its speed is influenced by geographical location and occurs faster in areas in the middle of large continents.

Stages in Ecological Succession

It Involves directional changes in vegetation.

- ❖ **Pioneer Community:** The first plant to colonize an area.
- ❖ **Successional Stages/Seres:** Progressive series of changes where one community replaces another. Transitional communities are also replaced (seral community) and characterized by increased productivity, nutrient shift, organism diversity, and food web complex.
- ❖ **Climax Community:** Final stage, stable and mature. It is more complex and long-lasting.

Type of Ecological Succession

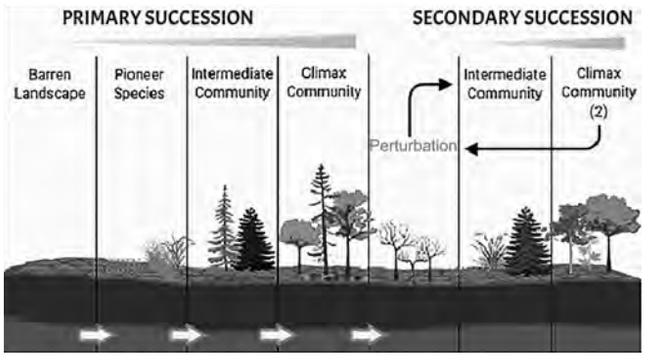


Fig. 10.5: Ecological Succession

Primary Succession:

- ❖ Occurs in areas where no previous community existed i.e. bare, often harsh environments (rock outcrops, sand dunes).
- ❖ **Pioneer species**: Hardy species like microbes, mosses, and lichens (symbiotic association of Fungi and algae) Species like Cnidarians, Fungi, Protozoa can establish a symbiotic relationship with other organisms.
- ❖ Pioneers alter the habitat through growth and development.
- ❖ **Relatively slow,** starting from barren conditions.

Secondary Succession:

- ❖ Follows **complete** or **partial destruction of an existing community** by natural events like floods, droughts, fires or by human interventions like deforestation, agriculture etc.
- ❖ Well-developed **soil already present** at the site.
- ❖ Hardy grasses initially, followed by herbaceous plants and eventually trees.
- ❖ **Faster,** as it builds upon existing soil and community remnants.

Types of Succession Based on Cause

- ❖ **Autogenic succession:** Brought about by biotic components (living inhabitants) of that community itself.
- ❖ **Allogenic succession:** Brought about by the abiotic components (fire, flood) of the ecosystem.

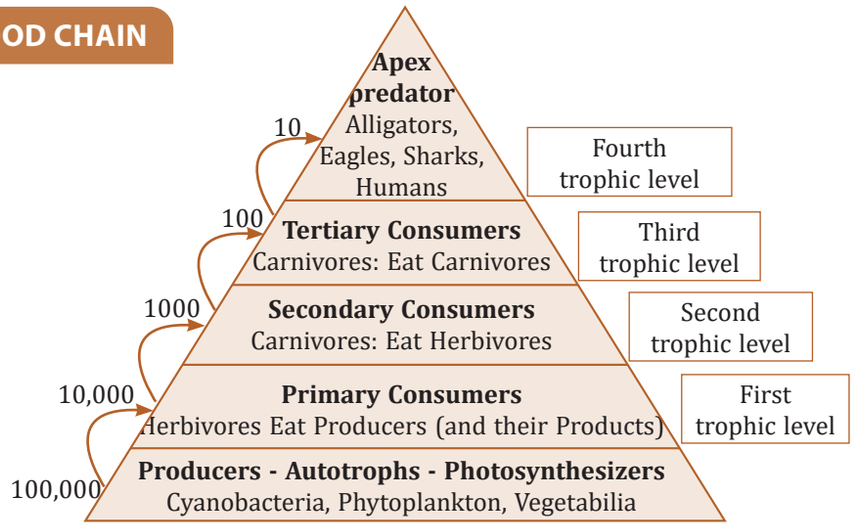
Type of Succession based on Habitats

- ❖ **Xerarch Succession:** Occurs on land with low moisture content (e.g., bare rock)
  - ➢ **Pioneers:** Colonizing plants adapted to arid conditions
  - ➢ **Progression:** Succession leads to mesophytic habitat (moderate water)
- ❖ **Hydrarch Succession:** Takes place in water bodies (ponds, lakes)
  - ➢ **Pioneers:** Phytoplankton in primary succession
  - ➢ **Progression:** Phytoplankton → Floating angiosperms → Rooted hydrophytes → Sedges/ grasses → Trees.

- **Lithosere (Rock-Based Succession)**
  - A type of primary succession starting on bare rocks.
  - **Stages:**
    - Lichens and mosses break down rock to form soil. Followed by grasses, shrubs, and trees.
    - Psammosere (Sand-Based Succession)
- Succession occurring on sand dunes.
  - **Stages:**
    - Pioneer plants like marram grass stabilize the sand.
    - Gradual development of shrubs and woodland.
    - Halosere (Saltwater-Based Succession)
- Succession in saline environments like salt marshes or mangroves.
  - **Stages:**
    - Begins with salt-tolerant plants (halophytes).
    - Progresses to less salt-tolerant species as soil salinity decreases.

ENERGY FLOW THROUGH THE FOOD CHAIN

- **Trophic level** represents energy flow in an ecosystem. A trophic level is a position occupied by an organism in a food chain.
- **Unidirectional Energy Flow:** Energy in an ecosystem flows in a unidirectional manner, typically from the lower trophic levels to the higher ones. This means that energy is transferred from producers (plants or autotrophs) to consumers (herbivores, carnivores, etc.) and rarely moves in the opposite direction.
- **Energy Loss in Trophic Levels:** At each trophic level, there is a significant loss of energy, primarily in the form of heat, during the process of metabolism and other life activities. This is often represented by the **ecological pyramid**, where the energy decreases as you move up the trophic levels.



Lindeman's Law of ten percent (10%)
The Efficiency of Energy Transfer from one Trophic level to the next is about 10%

- **The Lindeman's 10 Percent Law:** Lindeman's 10 percent law, proposed by ecologist Raymond Lindeman, states that only about 10 percent of the energy available at one trophic level is transferred to the next trophic level in an ecosystem.

Trophic Level Interaction

The trophic level interaction involves three concepts, namely:

- **Food Chain**
- **Food Web**
- **Ecological Pyramids**

Food Chain

A **food chain** represents the feeding relationships in an ecosystem, describing how energy and nutrients flow from one organism to another. It shows "who eats whom" in a linear sequence.

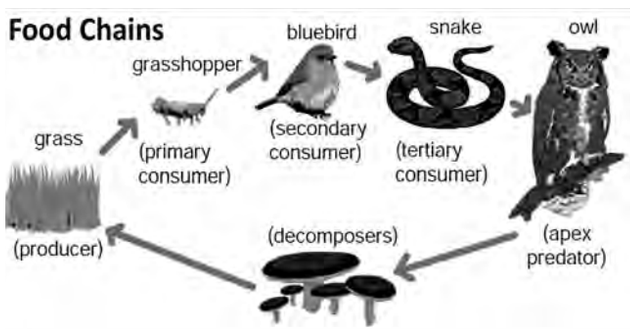


Fig. 10.6: Food Chains

Types of Food Chains

Aspect	Grazing Food Chain	Detritus Food Chain
Primary Energy Source	Living producers (plants).	Decomposing organic matter (detritus).
Initial Organism	Herbivores (consume living producers).	Decomposers (break down dead organic matter).
Intermediate Consumers	Carnivores (consume herbivores).	Detritivores (consume detritus).Some detritivores are **Earthworms, Millipedes, and Woodlice**.
Energy Flow	Direct consumption pathway.	Indirect consumption pathway through decay.
Example	Grass → Grasshopper → Frog → Snake. Diatoms→ Crustaceans (Krills, Prawns, Lobsters, Crabs, Barnacles, Copepods) → Herrings (small Fish).	Fallen leaves → Earthworms → Birds.

- On Earth, the **grazing food chain is dominant** in the marine ecosystem.
- In the **terrestrial ecosystem**, the **detritus food chain is more dominant**.
- Honey Bees perform a waggle dance for others of their kin to indicate the direction and the distance to a source of their food

Food Web

A food web refers to the complex network of feeding relationships among various organisms in an ecosystem, depicting multiple interconnected food chains.

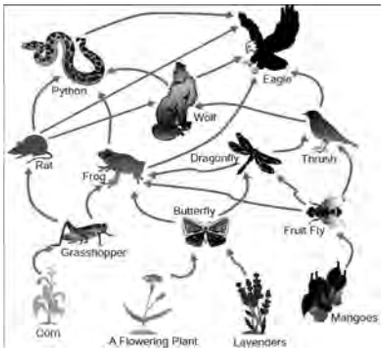


Fig. 10.7: Food Web

Types of Biotic Interactions in a Food Web

Interaction	Definition	Example 1	Example 2	Example 3
Mutualism	Both species benefit from the interaction.	Bee pollinating flowers, both get nectar and pollen.	Clownfish and sea anemones, mutual protection.	Lichen (fungus and algae), mutualistic relationship.
Commensalism	One species benefits, the other is unaffected.	Barnacles attaching to whales, barnacles benefit, whales unaffected.	Epiphytic plants growing on tree branches, plants benefit, tree unaffected.	Remoras hitching a ride on sharks, remoras get protection and scraps, shark unaffected.
Parasitism	One species benefits at the expense of the other.	Tick feeding on a dog's blood, tick benefits, dog harmed.	Tapeworms living in the intestines of animals, tapeworm benefits, host harmed.	Mosquitoes feeding on human blood, mosquitoes benefit, humans harmed.

Interaction	Definition	Example 1	Example 2	Example 3
Predation	One species kills and consumes the other.	Lion hunting and eating a zebra.	Snake capturing and eating a mouse.	Eagle preying on fish in a river.
Competition	Both species are negatively affected by sharing limited resources.	Lions and hyenas competing for prey in the savanna.	Plants competing for sunlight and nutrients in a forest.	Birds competing for nesting sites in a tree.
Amensalism	One species is harmed, the other is unaffected.	Black walnut trees releasing toxins that inhibit the growth of nearby plants.	Antibiotic-producing bacteria inhibiting the growth of other bacteria.	Allelopathic plants releasing chemicals that inhibit the growth of nearby plants.
Facilitation	One species indirectly benefits another.	Nurse plants providing shade and shelter for seedlings.	Coral reefs providing habitat for a diverse range of marine species.	Dead trees providing nesting sites for woodpeckers and other cavity-nesting birds.

Ecological Pyramids

Graphical presentation of the relationship between various trophic levels. Horizontal bars depict specific trophic levels, with the length of the bar indicating the total number of individuals, biomass, or energy at each trophic level.

Categories of Ecological Pyramids

- **Pyramid of Numbers:** Represents the number of individuals at each trophic level. Generally, numbers decrease as you move up the pyramid.

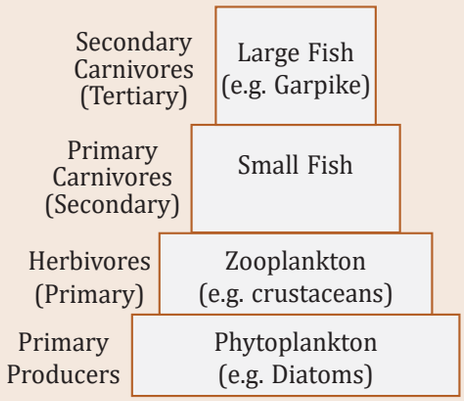


Fig. 10.8: Pyramid of Number

- **Pyramid of Biomass:** Depicts total biomass **(dry weight)** of organisms at each trophic level. Generally, biomass decreases as you move up due to energy loss.

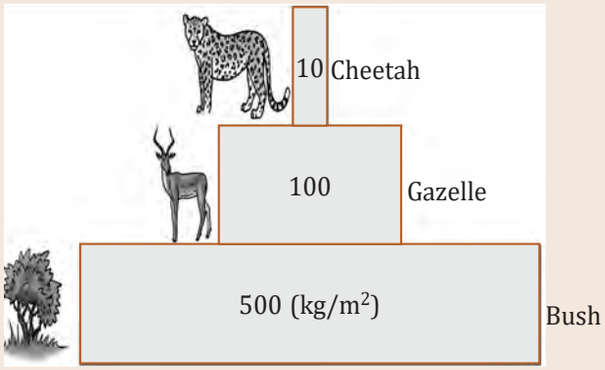


Fig. 10.9: Pyramid of Biomass

❖ **Pyramid of Energy or Productivity:** Represents energy flow through trophic levels. Generally, energy availability decreases moving up the pyramid, hence the pyramid is always upward.

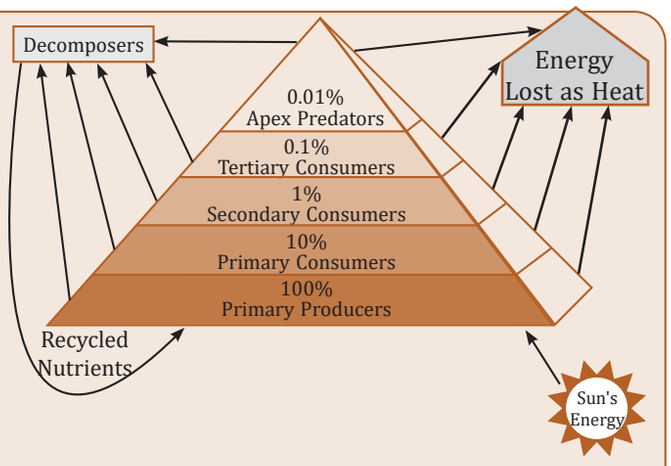


Fig. 10.10: Pyramid of Energy

Ecosystem	Pyramid of Energy	Pyramid of Biomass	Pyramid of Numbers
Grassland	Upright	Upright	Upright
Aquatic	Upright	Inverted	Upright
Forest	Upright	Upright	Spindle Shaped
Parasite food-Chain	Upright	Upright	Inverted

Inverted Aquatic Biomass Pyramid: In aquatic ecosystems, the biomass pyramid is often inverted because phytoplankton, the primary producers, have a low standing biomass due to their rapid turnover, despite their high production rates. This allows for a larger biomass of primary and secondary consumers, such as zooplankton and fish, to be supported. The efficient energy transfer from small producers to large consumers contributes to the inverted pyramid structure.

Inverted Detritus Pyramid of Numbers: The detritus pyramid of numbers can be inverted because large, slowly decomposing detritus (like fallen trees) can support a large number of smaller detritivores. Although the biomass of detritivores is low, their numbers can be much higher than the biomass of the detritus, leading to an inverted pyramid where fewer large detritus items support many smaller decomposers. and An inverted pyramid of biomass is typically found in marine (aquatic) ecosystems because the biomass of phytoplankton is lower than that of consumers at a given time.**(RAS 2021)**

MOVEMENT OF NON-DEGRADABLE POLLUTANTS IN ECOSYSTEMS

Non-degradable pollutants (persistent pollutants) cannot be easily broken down by detritivores. For instance, Chlorinated Hydrocarbons (Perfluoro Chlorides) are particularly damaging and long-lasting. The movement of these pollutants involves: Bioaccumulation and Biomagnification.

Bioaccumulation Vs Biomagnification

Aspect	Bioaccumulation	Biomagnification
Definition	Gradual buildup of pollutants **in an organism** over time.	Progressive increase in pollutant concentration **across trophic levels** in a food chain.
Mechanism	Pollutants accumulate when the rate of intake exceeds the rate of excretion or breakdown.	Higher trophic levels consume organisms with accumulated pollutants, leading to magnified levels.
Substance Characteristics	Persistent, long-lasting pollutants with low degradation (e.g., DDT).	Long biological half-life, fat-soluble, and insoluble in water (e.g., DDT).
Key Example	Accumulation of mercury in fish.	Increase in mercury concentration from small fish to larger predatory fish to humans.
Impact on Organism	Affects individual organisms, leading to potential toxicity or health issues.	Amplifies impact at higher trophic levels, affecting entire ecosystems.
Process	Within a single organism over its lifetime.	Across the food chain through predator-prey relationships.

NUTRIENT CYCLING (BIOGEOCHEMICAL CYCLES)

- Cyclic movement of nutrients and elements (like carbon, nitrogen, phosphorus, and water) between living (biotic) and non-living (abiotic) components of the Earth is called nutrient cycling.
- **Types of Nutrient Cycles**
- Nutrient cycles are classified into **perfect** and **imperfect** types based on the speed of replacement.
  - **Perfect Nutrient Cycle:** Nutrients are replenished as quickly as they are used. Gaseous cycles, such as the carbon, nitrogen, and water cycles, are typically perfect, with rapid nutrient replacement.
  - **Imperfect Nutrient Cycle:** Nutrients are not replaced as quickly as they are consumed, often linked to sedimentary cycles. Some nutrients become locked in sediments and are temporarily unavailable.
  - **Gaseous Cycle:** In this cycle, the atmosphere or hydrosphere acts as the reservoir. Examples include the water, carbon, nitrogen, and methane cycles.
  - **Sedimentary Cycle:** The earth's crust serves as the reservoir for sedimentary cycles. Examples include the phosphorus, sulfur, calcium, and magnesium cycles.

CARBON CYCLE

It involves an exchange between the atmosphere and organisms. Typically considered a **short-term cycle.** Cycle steps include:

- Carbon is mainly in the form of carbon dioxide in the atmosphere.
- **Photosynthesis** absorbs carbon into green plants and phytoplankton.
- **Respiration and decomposition** return carbon to the atmosphere.
- Some carbon enters a long-term cycle in marshy soil, aquatic sediments, or fossil fuels. Long-term carbon may take a long time to be released, such as in marshy soil or bottom sediments. In deep oceans, carbon can remain buried for millions of years until geological movements expose rocks above sea level.
- **Fossil fuels (coal, oil, natural gas)** are organic compounds that were buried before getting decomposed. Through geological processes, they transformed into fossil fuels. When burned, the stored carbon is released back into the atmosphere as carbon dioxide.
- **Congo Basin** has the world's largest tropical peatland, which holds about three years worth of global carbon emissions from fossil fuels; and the possible destruction of which can exert detrimental effect on the global climate.

NITROGEN CYCLE

- Nitrogen in the atmosphere is converted into ammonia, nitrites, or nitrates in the nitrogen cycle.
- **Sources of Nitrogen:**
  - Lightning, ultraviolet radiation, industrial processes, forest fires, automobile exhausts, and thermal power-generating stations contribute to atmospheric nitrogen oxides (NO, NO_2, N_2O).
  - Animal waste like urea, uric acid, dead vegetation & organisms add nitrogen as nitrates directly into the soil.
  - Burning coal releases CO, CO_2, sulphur dioxide and nitrogen oxides. Oxides of nitrogen fall on earth as smog and acid rain. Acidic rain is a complex mixture of nitrous, nitric, sulphurous, and sulfuric acids.

Nitrogen Cycle Steps: N_2 Fixing → Nitrification → Ammonification → Denitrification

- **Nitrogen fixation** is done by N_2-fixing microbes, industrial processes, and lightning.
- **N2-fixers:** Microbes with nitrogenase (nitrogen reduction enzyme) fix atmospheric nitrogen into ammonia and ammonium ions. Examples include free-living soil bacteria **(e.g., Azotobacter), symbiotic nitrogen-fixing bacteria (e.g., Rhizobium), and some cyanobacteria. (RAS 2016)**
- **Nitrogen-fixing plants** include Alfalfa, Chickpea, Clover , Peas, Beans , Soybean and Lentils . These plants improve soil fertility by converting atmospheric nitrogen into forms usable by plants.
- **Nitrification** oxidizes ammonia to nitrites and nitrates. Ammonium ions are oxidized to nitrites and then to nitrates by specialized nitrifying bacteria (**Nitrosomonas, Nitrococcus, Nitrobacter**). **Nitrates are absorbed by plants** and reduced to ammonia in leaves, forming amino acids.
- **Ammonification:** Bacteria convert nitrogenous waste products (urea, uric acid) and dead remains into ammonia/ammonium ions.
- **Denitrification** reduces nitrates to elemental nitrogen, e.g by special denitrifying bacteria (**pseudomonas and thiobacillus**). This nitrogen escapes into the atmosphere, thus completing the cycle.

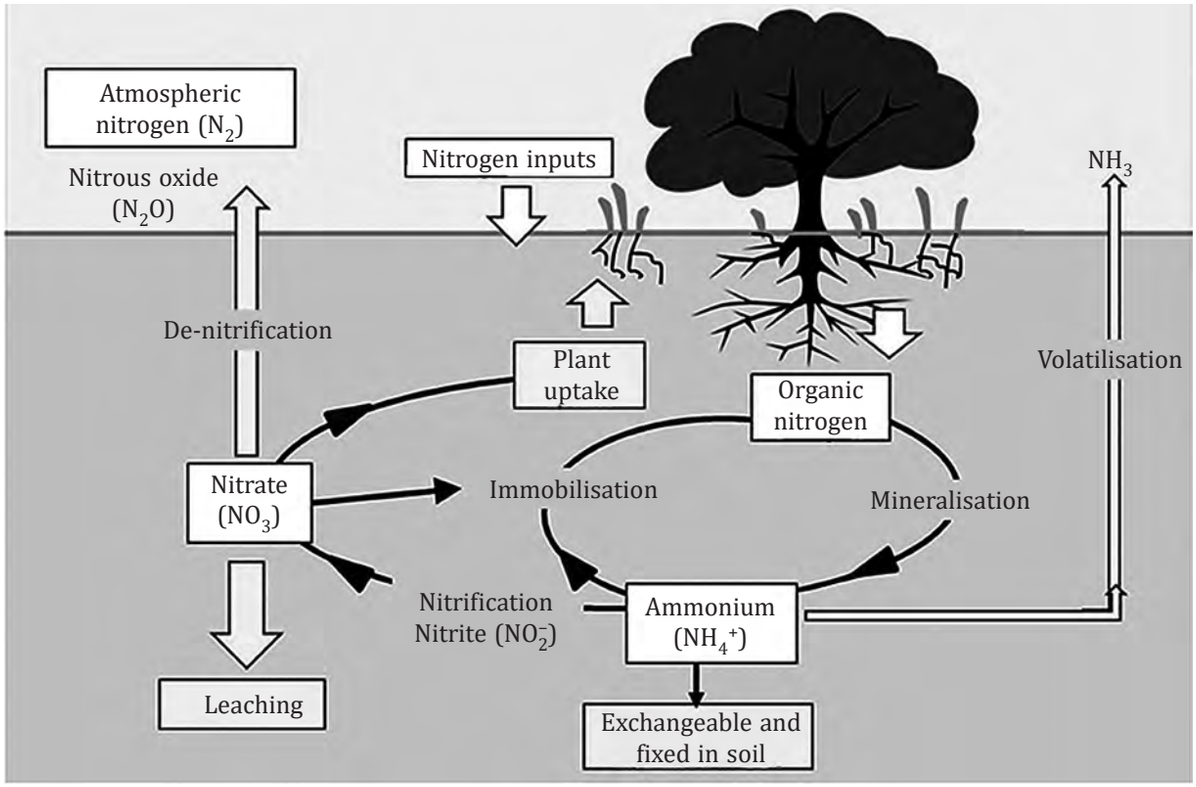


Fig. 10.11: Nitrogen Cycle

OXYGEN CYCLE

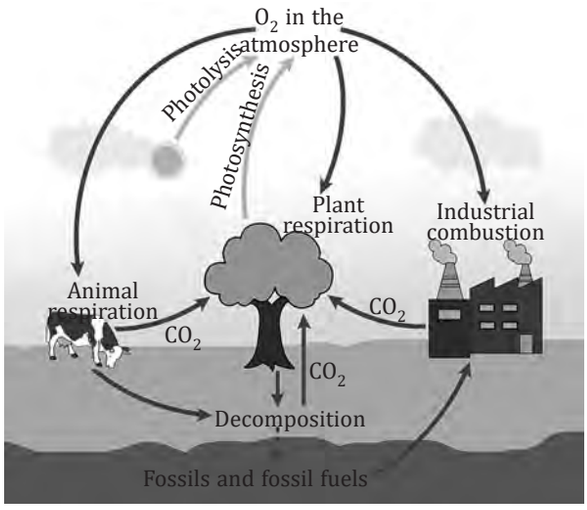


Fig. 10.12: Oxygen Cycle

The oxygen cycle regulates oxygen (O_2) distribution in Earth's atmosphere, biosphere, hydrosphere, and lithosphere, supporting life processes like respiration and combustion. Understanding the cycle is key to ecosystem dynamics and global biogeochemical cycles.

Reservoirs of Oxygen

- **Atmosphere:** 21% oxygen, produced by photosynthesis.
- Biosphere: Oxygen in biological molecules, produced by photosynthesis and consumed in respiration.
- **Hydrosphere:** Oxygen dissolved in water, supporting aquatic life.
- **Lithosphere:** Oxygen in Earth's crust, cycled through geological processes.

Flow Processes:

- **Photosynthesis:** Organisms like plants and algae produce oxygen using sunlight, water, and CO_2.
- **Respiration:** Organisms consume oxygen for energy, producing ATP and water.
- **Combustion:** Rapid oxidation of organic matter releases energy, heat, and CO_2.
- **Diffusion and Exchange:** Oxygen moves between reservoirs, supporting metabolic functions.

Exchanges:

- **Atmosphere-Biosphere:** Oxygen is produced by photosynthesis and consumed during respiration.
- **Hydrosphere-Lithosphere:** Oxygen exchanges in aquatic environments and through geological processes.
- **Human Activities:** Deforestation reduces oxygen production, while urbanization and industry contribute to oxygen depletion.

METHANE

- Methane (CH_4) is a more potent greenhouse gas (GHG) than carbon dioxide (CO_2). Despite its potency, methane has a shorter atmospheric lifetime than carbon dioxide.
- **Natural Sources of Methane:**

Natural Source	Description
Wetlands	Methanogens (prokaryotic archae-bacteria) in hypoxic (low oxygen) conditions produce methane during the decomposition of organic matter. Wetlands contribute approximately 80% of global methane (CH_4) emissions from natural sources.
Termites	Microbes in the guts of termites produce methane through anaerobic fermentation during digestion.
Oceans	Methane is produced by:
	❖ Anaerobic digestion in marine zooplankton and fish.
	❖ Methane production in sediments and drainage areas.
Methane Hydrates	Formed when hydrogen-bonded water and methane gas interact under high pressures and low temperatures in oceans. Found as crystalline ice in deep ocean sediments or trapped in permafrost.
	Destabilization Risks: Ocean acidification, climate change, or anthropogenic disturbances can release large amounts of methane, potentially causing mass extinction.

- **Human Sources of Methane Emissions:** Globally, 50-65% of total CH_4 emissions come from human activities, with significant contributions from: Agriculture (40%), Fossil Fuels (35%), Waste (20%).
- **Specific Human Sources:**

Human Source	noitpircseD
Landfills	Methane is generated as waste decomposes under anaerobic conditions.
Wastewater Treatment	Methane is produced during treatment processes if conducted in the absence of oxygen (anaerobic conditions).
Fossil Fuels	Methane is released during the production, storage, and transmission of natural gas. Additionally, methane trapped in coal deposits is released during coal mining (Coalbed Methane).
Livestock	Domesticated livestock, such as cattle, emit methane during their digestive processes (enteric fermentation).
Rice Cultivation	Flooded rice fields produce methane as organic matter decomposes under water.
Biomass Burning	Incomplete combustion of organic matter releases methane.

Human source > Natural Source

Natural Source: Wetlands > Termites > Oceans > Methane Hydrates

Human Source: Agriculture > Fossil Fuels > Waste

- **Methane Sink:** Soils act as a major sink for atmospheric methane through methanotrophic bacteria that use methane in a process called Methane Oxidation.
- **Removal from Atmosphere:** Methane is removed from the atmosphere by reacting with the hydroxyl radical (OH), converting it to CO_2 and water vapor. Hydroxyl radicals (cleanser of the atmosphere) are a form of sink because they scrub the atmosphere clean of pollutant molecules and break them down.
- **Impact of Methane:** Contributes to the formation of ground-level ozone, a dangerous air pollutant. Methane hydrates can release a significant amount of methane with warming, contributing to climate change.

THE PMOH CYCLE: PHOTOSYNTHESIS, METHANOGENESIS, AND HYDROXYL RADICAL CYCLE

The PMOH cycle describes the interconnected processes of carbon and methane transformations within ecosystems, involving photosynthesis, methanogenesis, and hydroxyl radical oxidation.

Photosynthesis: Carbon Fixation and Biomass Creation

- **CO_2 Utilization:** Atmospheric and soil-respired CO_2 is fixed by plants into glucose via the **Calvin Cycle**.
- **Conversion:** Glucose is transformed into various carbon compounds such as **proteins**, **monoterpenes**, **fats**, **cellulose**, and **root exudates**.
- **Biomass Role:** Part of the CO_2 becomes plant biomass, some is stored, and some is respired back into the atmosphere to be reused in photosynthesis.

Methanogenesis: Rumen Fermentation

- **Consumption by Cattle:** Cellulose in plant biomass is ingested by ruminants like cattle.
- **Fermentation in Rumen:** Microbial communities, including methanogenic archaea, convert cellulose into:
  - **Short-Chain Fatty Acids (SCFAs):** Utilized by cattle to build fats and proteins.
  - **Hydrogen (H_2):** An intermediate by-product.
  - **Methane (CH_4):** Released as a by-product primarily through "burping."

Hydroxyl Radical Oxidation: Methane Breakdown

- **CH_4 in Atmosphere:** Methane released into the atmosphere interacts with **hydroxyl radicals (OH)** via **hydroxyl oxidation**, breaking down into:
  - **CO_2:** Reintroduced into the photosynthesis cycle.
  - **Water Vapor (H_2O):** Joins the hydrological cycle, contributing to rain or forming more hydroxyl radicals through interaction with excited oxygen.

Cycle Repetition

- The CO_2 and H_2O produced re-enter the photosynthesis process, completing the PMOH cycle.

Significance of the PMOH Cycle

- **Carbon Recycling:** Efficient use of CO_2 through fixation, biomass conversion, and methanogenesis.
- **Methane Dynamics:** Role of livestock and microbial methanogenesis in the carbon cycle.
- **Atmospheric Methane Regulation:** Hydroxyl oxidation as a natural mechanism for CH_4 breakdown, mitigating its greenhouse effect.
- **Ecosystem Interconnectivity:** Integration of biological, atmospheric, and hydrological processes.

PHOSPHORUS CYCLE

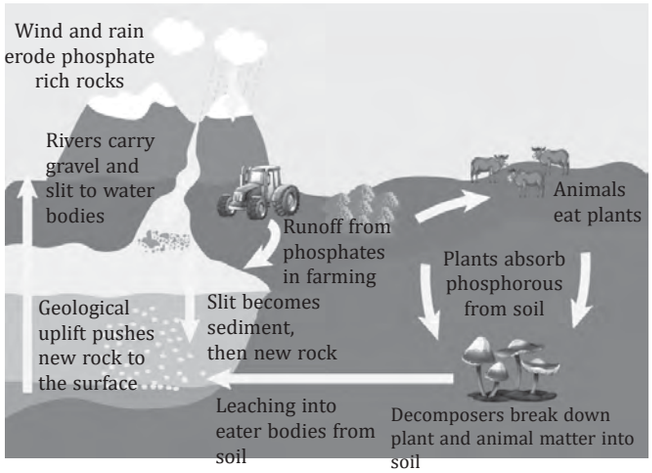

Wind and rain erode phosphate rich rocks
Rivers carry gravel and slit to water bodies
Runoff from phosphates in farming
Animals eat plants
Plants absorb phosphorous from soil
Slit becomes sediment, then new rock
Geological uplift pushes new rock to the surface
Leaching into eater bodies from soil
Decomposers break down plant and animal matter into soil

Fig. 10.13: Phosphorus Cycle

- Phosphorus cycle involves the movement of phosphates from rocks to rivers and oceans, then back to the crust through geological processes.
- **Sources of Phosphorus:** Phosphorus occurs as a mineral in phosphate rocks, unlike carbon and nitrogen that come primarily from the atmosphere.
- **Phosphorus Cycle Steps:**
  - Weathering, erosion, and mining release phosphates, which enter rivers and oceans.
  - In the ocean, phosphates accumulate on continental shelves as insoluble deposits.
  - Over millions of years, crustal plates rise from the seafloor, bringing phosphates to the crust, and the geochemical phase of the cycle repeats.
  - Phosphorus plays a central role in aquatic ecosystems and water quality, contributing to phytoplankton blooms in lakes and eutrophication

SULPHUR CYCLE

- The sulphur cycle includes atmospheric input, deposition as acid rain, plant uptake, transfer through the food chain, and return to soil and water through excretion and decomposition.
- **Sources of Sulphur:** Sulphur is locked in organic (coal, oil, peat) and inorganic (pyrite rock, sulphur rock) soil deposits as sulphates, sulphides, and organic sulphur. Released by weathering of rocks, erosional runoff, and decomposition of organic matter, it is carried to terrestrial and aquatic ecosystems in salt solutions.
- **Steps in the Sulphur Cycle**

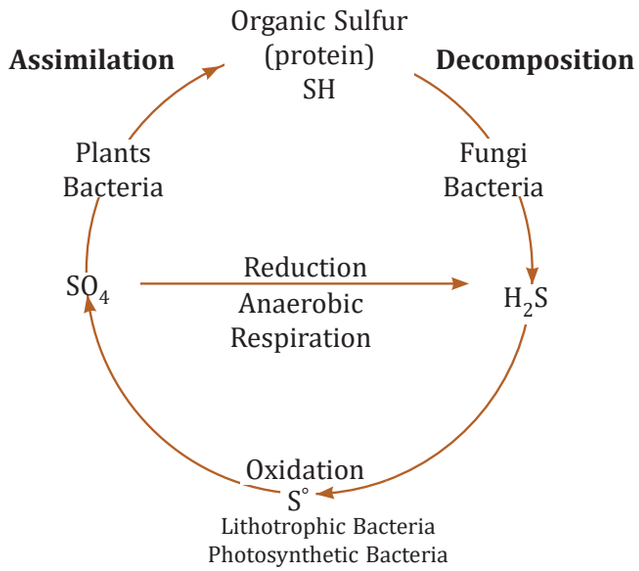


Fig. 10.14: Sulphur Cycle

  - **Atmospheric Input:** Sulphur enters the atmosphere as sulphur dioxide from volcanic eruptions, combustion of fossil fuels, ocean surfaces (Dimethyl Sulfide - DMS), and gases released by decomposition. DMS is an organosulfur compound derived from marine algae, plants, and animals,

serving as a primary source of marine sulphate aerosols.

- **Atmospheric Deposition:** Sulphur dioxide in the atmosphere is carried back to the earth as weak sulphuric acid (acid rain). {Acid rain is primarily caused by sulfur dioxide (SO_2) and nitrogen oxides (NO_x), which form sulfuric and nitric acids in the atmosphere.(RAS 2018/2013)}
- **Plant Uptake:** Sulphates in the form of atmospheric deposition or other sources are taken up by plants. Incorporation into sulphur-bearing amino acids occurs through metabolic processes.
- **Food Chain Transfer:** Sulphur, incorporated into amino acids, passes through the grazing food chain.
- **Return to Soil and Water:** Sulphur bound in living organisms is returned to the soil, bottom of ponds, lakes, and seas through excretion and decomposition of dead organic material.

ECOSYSTEM SERVICES AND GOODS

Ecosystem services

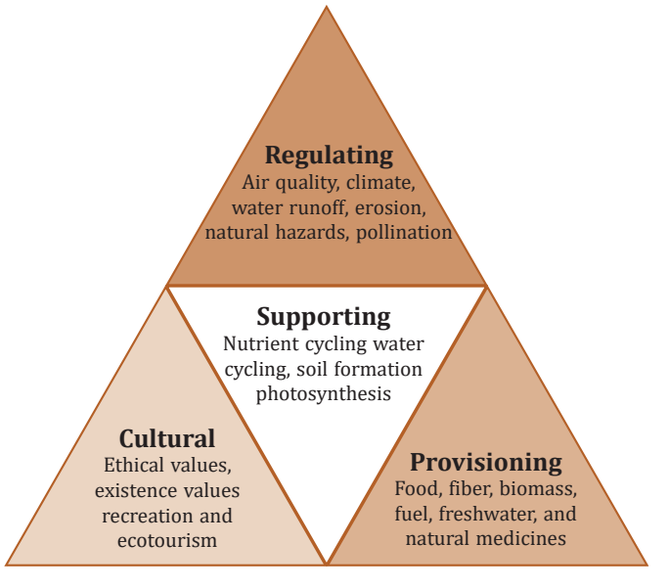

Regulating
Air quality, climate, water runoff, erosion, natural hazards, pollination
Supporting
Nutrient cycling water cycling, soil formation photosynthesis
Cultural
Ethical values, existence values recreation and ecotourism
Provisioning
Food, fiber, biomass, fuel, freshwater, and natural medicines

Fig. 10.15: Ecosystem Services

- Diverse benefits provided to humans by the natural environment and from healthy ecosystems.
- The Millennium Ecosystem Assessment describes the following major categories of ecosystem services: cultural, provisioning, regulating and supporting.

Ecosystem goods

- Natural products harvested by humans from the environment, such as wild fruit and nuts, forage, timber, game, natural fibres, medicines, etc. For Example- Lemongrass is used in preparing a natural mosquito repellent.
- **Natural Capital:** ecosystems providing invaluable ecosystem services. E.g., Flood protection by mangroves.

Ecosystem Valuation

Economic process assigning monetary value to an ecosystem and its services; tool for policymakers to evaluate management impacts and compare a cost-benefit analysis of potential policies.

The Economics of Ecosystems and Biodiversity (TEEB)

- Study hosted by the United Nations Environment Programme (UNEP) and led by Indian environmental economist Pavan Sukhdev.
- **Objectives:** To establish a global standard for natural capital accounting, mainstream the values of biodiversity and ecosystem services into decision-making at all levels, and highlight the growing cost of biodiversity loss.

ECOSYSTEM PRODUCTIVITY

Ecosystem productivity refers to the rate at which energy is produced and transferred within an ecosystem. It is measured as the generation of biomass.

Ecosystem Productivity

Ecosystem productivity refers to the rate at which energy is captured and stored by producers (like plants) in an ecosystem. It is categorized as:

- **Gross Primary Productivity (GPP):** Total energy fixed by plants through photosynthesis.
- **Net Primary Productivity (NPP):** Energy left after plants use some for respiration (NPP = GPP – Respiration).

Factors Influencing Productivity

- **Climate:** Temperature, sunlight, and water availability.
- **Nutrient Availability:** Higher nutrients often lead to higher productivity.
- **Biodiversity:** More species can lead to efficient energy utilization.

Productivity Ranking of Major Ecosystems

Ecosystem	NPP (g/m^2/ year)	Characteristics
Tropical Rainforests	~2,200	High sunlight, temperature, and rainfall; dense biodiversity.
Coral Reefs	~2,000	Warm, shallow waters with symbiotic relationships (e.g., coral and algae).

Ecosystem	NPP (g/m^2/ year)	Characteristics
Estuaries	~1,800	Nutrient-rich zones where rivers meet the sea; high productivity and fish nurseries.
Temperate Forests	~1,200	Seasonal climates with moderate rainfall and biodiversity.
Grasslands	~600-800	Open lands with grasses; moderate productivity due to limited water.
Lakes and Rivers	~250-500	Productivity varies with nutrient content and sunlight penetration.
Deserts	~50-200	Extremely low due to harsh climates and water scarcity.
Open Oceans	~125	Low nutrient availability limits productivity despite vast area.
Tundra	~100	Cold, harsh conditions with short growing seasons limit productivity.

Global Importance

- **Tropical Rainforests:** Major oxygen producers, carbon sinks, and biodiversity reservoirs.
- **Coral Reefs and Estuaries:** Critical for marine biodiversity and coastal economies.
- **Grasslands and Temperate Forests:** Vital for agriculture and timber industries.
- **Deserts and Oceans:** Though less productive, deserts are key for specific biodiversity, and oceans are critical for global carbon cycling.

Secondary Productivity

Secondary productivity refers to the rate at which energy is assimilated by consumers (herbivores, carnivores, omnivores, and detritivores) in an ecosystem. It represents the transfer of energy from producers to higher trophic levels through consumption.

Importance of Secondary Productivity

- **Energy Transfer:** Determines the energy available to higher trophic levels, including apex predators.
- **Ecosystem Stability:** Supports food webs and species diversity.
- **Human Relevance:** Impacts food production systems, including livestock and fisheries.

TYPES OF ECOSYSTEMS

There are broadly **two types** of ecosystems:

- **Natural Ecosystem:** An assemblage of plants and animals which functions as a unit and can maintain its identity on its own.
  - Terrestrial Ecosystem /Biomes
  - Aquatic Ecosystem

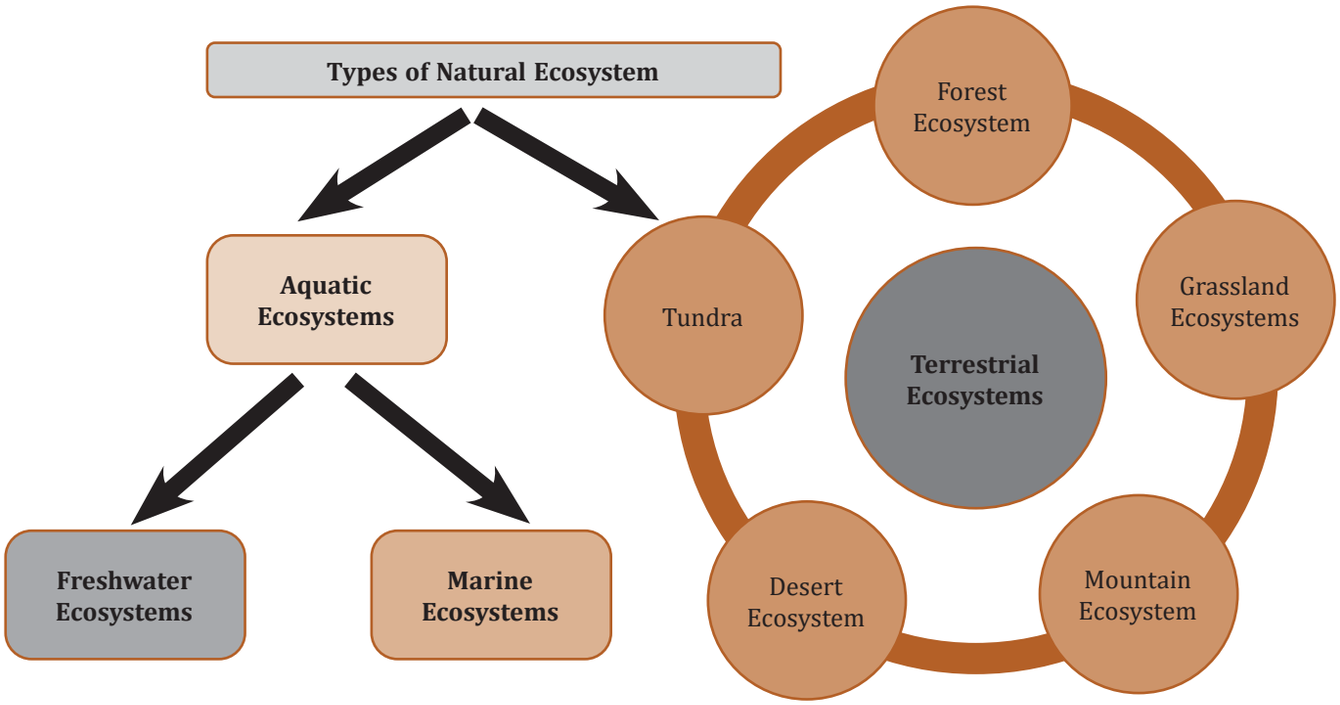


Fig. 10.16: Types of natural Ecosystem

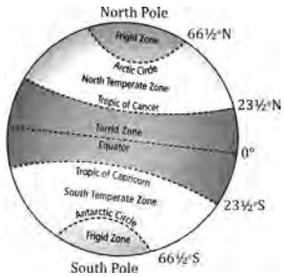
- **Artificial Ecosystem:** Human-made structures where biotic and abiotic components are made to interact with each other for survival. It is not self-sustaining and can perish without human help. Eg: aquariums, agriculture fields, zoos, etc.

Terrestrial Ecosystem Vs Aquatic Ecosystem

Aspect	Aquatic Ecosystems	smeStysocE lairsterreT
Habitat	Water bodies like oceans, rivers, lakes, and ponds.	Land surfaces, including forests, grasslands, deserts, and mountains.
Primary Producers	Algae, phytoplankton, and aquatic plants.	Grasses, trees, shrubs, and other terrestrial plants.
Primary Consumers	Zooplankton, fish, aquatic insects, and mollusks.	Herbivores like insects, birds, mammals, and reptiles.
Secondary Consumers	Predatory fish, larger aquatic insects, and carnivorous mammals like otters.	Predators like carnivorous mammals (e.g., lions, wolves), birds of prey, and snakes.
Oxygen Availability	Dissolved oxygen in water for aquatic organisms.	Atmospheric oxygen for terrestrial organisms.
Adaptations	Specialized structures like gills for respiration and fins for movement.	Features like lungs for respiration and limbs for movement.

TERRESTRIAL ECOSYSTEMS

These are exclusively **land-based** ecosystems. **The terrestrial part of the biosphere is divisible into enormous regions called biomes**. No two biomes are alike.



Tundra

- Two types of tundra – **Arctic and Alpine.**
- **Devoid of trees due to permafrost**, the lowest form of vegetation like mosses and lichens are sparsely found on bare rocks, coastal lowlands have reindeer moss which provides the only pasturage for reindeer.
- **Animals:** Reindeer, arctic fox, wolves, musk ox, polar bear, lemming, arctic hare, and arctic willow. **Reptiles and amphibians are almost absent**.
  - **Adaptation:** Most animals have a long life, thick cuticle and epidermal hair or fur. **Mammals have a large body size, small tails and ears to avoid heat loss from the surface**.

Forest

Taiga or Boreal Biome (Evergreen Coniferous forests)

- **Lowest productivity** amidst all forest ecosystems (harsh weather, thin and poor soils for agriculture. i.e., podzols).
- **Podzols** are very poor because weathering of rocks proceeds slowly in cold climates; litter derived from conifer leaves decomposes very slowly and is **not rich in nutrients** (low humus and organic matter, acidic soil, poor drainage, low pH); conifers do not shed their leaves frequently.
- **Vegetation:** Evergreen coniferous forest with species such as spruce, fir, and pine(require little moisture).
- **Animals:** Siberian tiger, wolverine, lynx, wolf, bear, red fox, squirrel, and amphibians like Hyla, Rana, etc.

Temperate Deciduous Biome (North Western Europe – British Type Climate)

- **Podzolic** and fairly **deep soil**.
- **Vegetation:** Deciduous (trees shed their leaves in the cold season); adaptation for protecting themselves against winter snow and frost. Shedding begins in autumn. Growth begins in spring. Eg: oak, elm, ash, birch, beech, and poplar. {Woody raw material is used for making paper pulp.(RAS 2013)}

Temperate Rainforest Biome

- **Less percentage of area** covered over Earth (north-western coast of N. America from N. California through S. Alaska; small areas in S. Chile, New Zealand, Australia and a few other places worldwide)
- **Vegetation:** Large coniferous trees including Douglas fir, Western red cedar, Mountain hemlock, Western hemlock, Sitka spruce, Lodgepole pine, mosses and lichens often growing as epiphytes (a plant that grows harmlessly upon another plant (commensalism)).

Sub-Tropical Deciduous Biome in Eastern China, South Eastern USA

- **Luxuriant Vegetation:** Lowlands- both evergreen broadleaved forests and deciduous trees (hardwood).

Highlands- various species of conifers, such as pines and cypresses.

Temperate Deciduous Biome (Mediterranean Climate)

- **Xerophytic** (drought tolerant) plants due to heat, dry air, excessive evaporation, and prolonged droughts.
- **Small broad-leaved trees** are widely spaced, never very tall.
- **Low, broad-leafed evergreen trees** (mostly evergreen oaks) in regions of adequate rainfall.
- **Frequent fire episodes**, adaptations of the plants enable them to regenerate quickly after being burnt.

Tropical Deciduous Biome (Monsoon Climate)

- **Drought-deciduous/dry deciduous/tropical deciduous forests**.
- **Vegetation:** Teak, neem, bamboo, sal, sheesham, sandalwood, khair, mulberry

Tropical Rainforest Biome

- High temperatures, abundant rainfall, luxuriant evergreen rainforests (lungs of the Earth), large number of species and epiphytes.
- **Vegetation:** mahogany, ebony, dyewoods, etc., mangrove forests (salty water).
- All plants, including epiphytes, struggle upwards for sunlight resulting in a peculiar layer arrangement **(canopy)**.
- In recent years **threatened by deforestation and burning**, 17 per cent of the entire rainforest and about 20 per cent of the Brazilian rainforest have been deforested.
- If a tropical rainforest is removed, it does not regenerate quickly as compared to a tropical deciduous forest. This is because the soil of the rainforest is deficient in nutrients.

Importance of Rainforests

- Produce ~20% of the earth's oxygen and act as **Carbon sink. (RAS 2023)**
- **Precipitation:** Responsible for creating 50-75 % of their precipitation through evapotranspiration.
- **Source of Many Rivers:** Amazon, Mekong, and Congo (Zaire) are fed by the rainforests.
- **Biodiversity:** >30 million species of plants and animals (half of the earth's wildlife and at least ⅔ rd of its plant species)
- **Commercial Agriculture:** Conducive climate for cultivating coffee, cocoa, palm, rubber, etc. (100-200 cm of rainfall).
- **Indigenous Communities:** depend on it for their food, shelter, medicines and subsistence agriculture (slash-and-burn agriculture).
- Controls **local and regional climates** as well as influences the **circulation of ocean currents.**

Mushroom

Some mushrooms exhibit diverse properties. Medicinal mushrooms like *Ganoderma lucidum* boost immunity and have anti-cancer benefits. Psychoactive species, such as *Psilocybe,* contain psilocybin, influencing brain activity. Insecticidal mushrooms like *Beauveria bassiana* are used for pest control, while bioluminescent varieties, such as *Mycena chlorophos*, produce natural light. These properties make mushrooms valuable in medicine, pest control, and ecological studies.

Grassland

Steppe or Temperate Grassland Biome

- **Practically treeless**, grasses are much shorter, fresh, and nutritious.
- Poleward, **transition to a zone of wooded steppes** due to increase in precipitation (some conifers may gradually appear).
- Do **not have much animal diversity**.

Savanna or Tropical Wet and Dry Biome (Tropical Shrublands and Grasslands)

- Characterised by **tall grass and short trees** (deciduous, umbrella-shaped broad trunks with water-storing devices, shed leaves in the cool dry season to prevent water loss through transpiration, **e.g., acacias**.
- **Rich in mammal, bird, and reptile diversity**.
- The vegetation of savannah consists of grassland with scattered small trees, but extensive areas have no trees. The forest development in such areas is generally kept in check by one or more or a combination of some conditions.
- In the grasslands, trees do not replace the grasses as a part of an ecological succession because of Water limits (due to seasonal rainfall) and fire.
- **Managed Fires:** Lighting dry savanna grasslands is a key ecosystem management activity by cattle farmers and authorities to stimulate the growth of fresh, nutritious grass for their animals, control the numbers of parasitic ticks or manage the growth of thorny scrub.
- **Fires in Savannahs are Carbon-neutral:** burn mainly dry grasses (CO_2 released is reabsorbed by growth of new grass).

Desert

Tropical and Mid-Latitude Desert Biome

- **Vegetation:** xerophytic or drought resistant. Eg: cacti, thorny bushes, long-rooted wiry grasses, scattered dwarf acacias.
- **Herbs and Grasses:** Thick, tough skins of seeds to protect them while they lie dormant.
- **Shrubs:** long, well-spaced roots to gather moisture and search for groundwater.
- **Plants:** Few or no leaves; waxy, leathery, hairy, or needle-shaped foliage to reduce water loss through transpiration.

AQUATIC ECOSYSTEM

Ecosystems present in a **body of water**. Broadly classified into **three sub-groups** based on salinity:

- **Freshwater Ecosystem:** low salt content due to continuous recycling of water; < 5 ppt). 2 types:
  - **Static/still water (Lentic) ecosystems:** ponds, lakes, bogs and swamps
  - **Running water (Lotic) ecosystems:** Springs, streams, rivers, etc.
- **Marine Ecosystem:** salt concentration **equal to or > seawater (i.e., 35 ppt or above)**. E.g., shallow seas and open oceans.
- **Brackish Water Ecosystems:** salt content **between 5 - 35 ppt.** e.g., estuaries, salt marshes, mangrove swamps and mangrove forests.

Classification of Aquatic Organisms (Based on the Zone of Occurrence)

- **Neuston:** Live at the air-water interface, e.g. floating plants.
- **Periphyton:** Remain attached to stems and leaves of rooted plants or substances emerging above the bottom mud, such as sessile algae. e.g. Water striders (insects), some species of algae.
- **Plankton:** Microscopic floating organisms such as algae (plant-like protists), diatoms, protozoans, larval forms, etc.
  - Includes microscopic plants like algae (phytoplankton – primary producers or autotrophs), animals like crustaceans and protozoans (zooplankton – heterotrophs).
  - If phytoplankton of an ocean is completely destroyed for some reason, the ocean as a carbon sink would be adversely Affected and the food chains in the ocean would be adversely affected.
  - Locomotory power of the planktons is limited so that their distribution is controlled, essentially, by currents in the aquatic ecosystems.
- **Nekton:** Powerful swimmers that can overcome water currents.
- **Benthos:** Found living at the bottom of the water mass. e.g. Fish, turtles, squid

Phytoplankton

- Tiny microscopic **autotrophs** found in the ocean. They have **chlorophyll** to capture sunlight and use photosynthesis to turn it into chemical energy.
- All phytoplankton **photosynthesise,** but some get additional energy by consuming other organisms.
- Phytoplankton include **diatoms , dinoflagellates, cryptomonads, green algae, blue-green algae, etc.**, which are at the base of the aquatic food web and are important ecological indicators.
- They **contribute to more than half of the oxygen that we breathe** and influence climate by absorbing human-induced CO_2.

Factors Limiting Productivity of Aquatic Ecosystems

Sunlight	❖ Determines the extent of plant distribution according to light penetration- photic and aphotic zones. ❖ **Photic (Euphotic) Zone):** extends from the water surface down to where the light level is 1% of that at the surface. Photosynthetic activity is confined to the photic zone. ❖ **Aphotic (Profundal) Zone:** light penetration and plant growth are restricted. It extends from the end of the photic zones to the bottom of the lake. No photosynthesis.
Dissolved Oxygen	❖ **Freshwater:** the average concentration of dissolved oxygen is **10 ppm by weight** (25-30 times lower than the concentration of oxygen in an equivalent volume of air). ❖ Oxygen enters: through the air-water interface and the photosynthetic activities of aquatic plants. ❖ Dissolved oxygen escapes: through the air-water interface, respiration, and decomposition of organisms. ❖ **Winterkill:** fish mortality event due to appearance of a layer of ice on top of a water body that effectively cuts off the light. Photosynthesis stops, but respiration continues causing depletion of dissolved oxygen, and the fish die. ❖ **Impact of Global Warming on Dissolved Oxygen** ➢ The amount of dissolved oxygen retained in water is indirectly proportional to temperature. Oxygen is less soluble in warm water. ➢ Warm water also enhances decomposer activity which further increases the rate at which oxygen is depleted in water. If dissolved oxygen levels fall below 3-5 ppm, many aquatic organisms are likely to die.
Temperature	Aquatic organisms are more prone to survival threats compared to terrestrial organisms owing to narrow temperature tolerance limits.
Eutrophication (RAS 2013)	Process of o**ver-enrichment of water body with nutrients (nitrogen, phosphorus),** leading to the **plentiful growth of simple plant life (algae, plankton)** eventually leading to anoxic conditions for the seagrass and other organisms.

WETLAND ECOSYSTEM

What are Wetlands?

Wetlands are ecosystems where water is the dominant factor influencing the environment, as well as the plant and animal life within it. These areas occur where the water table is at or near the surface or where land is periodically or permanently submerged.

According to the Ramsar Convention (Article 1.1):

"Wetlands are areas of marsh, fen, peatland, or water, whether natural or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish, or salt, including areas of marine water where the depth at low tide does not exceed six meters."

For site protection, Article 2.1 further expands the definition:

"Wetlands may include riparian and coastal zones adjacent to the wetlands, and islands or bodies of marine water deeper than six meters at low tide lying within the wetlands."

Types of Wetlands

Wetlands are broadly categorized into five natural types and human-made types:

Natural Wetlands

1. **Marine Wetlands (Coastal):** Include coastal lagoons, rocky shores, seagrass beds, and coral reefs.
2. **Estuarine Wetlands:** Found in deltas, tidal marshes, mudflats, and mangrove swamps.
3. **Lacustrine Wetlands:** Associated with lakes and their surroundings.
4. **Riverine Wetlands:** Found along rivers and streams, including floodplains.
5. **Palustrine Wetlands:** Encompass marshes, swamps, bogs, and other marshy ecosystems.

Human-Made Wetlands

Examples include:

- Fish and shrimp ponds
- Farm ponds
- Irrigated agricultural land, such as rice paddies
- Salt pans
- Reservoirs and dams
- Gravel pits, wastewater treatment ponds, and canals.

The **Ramsar Classification of Wetland Types** includes 42 categories grouped into:

- **Marine and Coastal Wetlands**
- **Inland Wetlands**
- **Human-Made Wetlands**

Key Features of Wetlands

- **Global Distribution:** Wetlands exist across all climates, from the tundra to the tropics.
- **Extent of Wetlands:**
  - The UNEP-World Conservation Monitoring Centre estimates wetlands cover about 570 million hectares (~6% of the Earth's land surface).
  - Other sources estimate the range to be between **748–778 million hectares** (minimum) and **999–4,462 million hectares** (maximum), depending on the inclusion of additional data.
- **Significant Ecosystems:**
  - **Mangroves:** Cover approximately **147,256 km km^2** globally.
  - **Coral Reefs:** An estimated **600,000 km^2** remain worldwide.
- **Marine Wetland Depth Criteria:**
  - Marine wetlands are considered up to a depth of **6 meters** at low tide, corresponding to the diving limit of sea ducks during feeding.
  - Waters deeper than 6 meters and islands within wetlands can also be protected under the Ramsar definition.
- **Inclusion of Lakes and Rivers:**
  - The Ramsar definition covers lakes and rivers entirely, irrespective of their depth.

Measures to Protect Wetlands of India

National Plan for Conservation of Aquatic Eco-systems (NPCA)	**Centrally Sponsored Schemes (CSS)** ❖ Formed by merging the **National Lake Conservation Plan (NLCA) + National Wetlands Conservation Programme (NWCP).** ❖ **Funding pattern of 70:30 (90:10 for the NE States)**. ❖ **MOEF coordinates**, and provides guidelines and financial and technical assistance to the state govt. ❖ **State/UT governments manage the aquatic ecosystems**. ❖ Criteria for identifying wetlands of national importance under NPCA are similar to those under the Ramsar Convention on Wetlands.

Wetlands (Conservation-Management) Rules 2010	❖ MoEF notified **legally enforceable rules** under the provisions of the **Environment (Protection) Act, 1986**, to ensure that there is no further degradation of wetlands. ❖ **Central Wetland Regulatory Authority (CWRA) (chairmanship of the Secretary, MoEF):** Ensure implementation of the Rules. ❖ **Wetlands classification** for better management and easier identification. ❖ **Specify and prohibit harmful activities** to wetlands (industrialisation, construction of permanent nature, solid waste dumping etc.) ❖ **Activities** like aquaculture, agriculture, harvesting of living and non-living resources, dredging to remove siltation, etc., may be carried out in the wetlands but **only with prior permission** from the concerned authorities. ❖ **Central Government may permit any prohibited activities** or non-wetland use in the protected wetland on the recommendation of CWRA. ❖ Encompasses the drainage area or catchment regions of the wetlands as determined by the authority.
Wetlands (Conservation and Management) Rules, 2017	**State Wetland Authority (SWA):** ❖ **Establishment** of a SWA in each state and union territory, led by the state's environment minister. ❖ **Composed** of experts in hydrology, socioeconomics, landscape design, fisheries, and wetland ecology. **Management Principles:** ❖ **Adoption** of the "smart use principle" for sustainable wetland management. ❖ **Emphasis** on "wise use" to balance conservation and utilization, with decentralized powers. ❖ Regulatory Functions of SWA: ❖ **Compilation** of activities requiring governance and approval within notified wetlands and their zones. ❖ **Authority** to prohibit activities harmful to wetlands and promote better utilization plans. ❖ **Community Engagement and Awareness:** SWA to **promote** awareness and **involve** local communities in wetlands conservation. ❖ **National Wetland Committee (NWC): Creation** of NWC, **replacing** the Central Wetlands Regulatory Authority, led by the MoEFCC secretary. ❖ **Prohibited Activities: Prohibition** on encroachment, industrial growth, waste disposal, and untreated waste discharge in wetlands. ❖ **State-Level Responsibilities:** State authorities must **compile** lists of wetlands and **identify** those needing notification within six months. ❖ **Digital Inventory: Development** of a comprehensive digital inventory of wetlands, **updated** every 10 years. ❖ **Wetlands of India Portal:** It includes capacity-building materials, data repositories, and dashboards for each state and union territory. ❖ **National Wetland Decadal Change Atlas:** Prepared by the Space Applications Centre (SAC), Ahmedabad, this atlas highlights the changes in wetlands across the country over the past decade. ❖ **Centre for Wetland Conservation and Management (CWCM):** Established on World Wetland Day 2021, this center focuses on addressing research needs and knowledge gaps in wetland conservation. ❖ **Wetlands Rejuvenation Programme:** Initiated by MoEFCC in 2020, this program aims to rejuvenate over 500 wetlands across India. It includes developing baseline information, rapid assessments, stakeholder engagement, and management planning. ❖ **Amrit Dharohar Scheme:** Launched with the Union Budget 2023-24, the Amrit Dharohar Scheme is a key initiative aimed at optimizing wetland utilization over the next three years.

RAMSAR CONVENTION

❖ **International treaty** established for " maintenance of ecological character for sustainable use of wetlands" signed on the **2nd Feb (World Wetlands Day)**, 1971, in the city of Ramsar in Iran.

❖ Covers over 2,400 Ramsar Sites, 2.5 million sq km worldwide. As of October 2025, there are 173 contracting parties to the Ramsar Convention. **India has been a party since 1982**.

❖ After acceding to the convention, a party must designate **at least one wetland** as a Wetland of International Importance.

- **2026 Theme :** "Wetlands and traditional knowledge: Celebrating cultural heritage"
- **World's first site:** the **Cobourg Peninsula in Australia** (1974)
- Countries with the **most Ramsar Sites**: **United Kingdom** (176) and Mexico (144).
- Country with the largest area under Ramsar protection: **Bolivia**
- India's Ramsar wetlands are spread over **11,000 sq km — around 10% of the total wetland area in the country** — across 18 States.
- As of July 2026, there are a total of 100 Ramsar sites in India.
- **Largest Site in India: Sundarbans** (West Bengal)

Criteria for Identification of Wetlands	❖ **Unique Wetland:** Contains rare or unique examples of a natural or near-natural wetland type. ❖ **Endangered Species:** Supports threatened, vulnerable, endangered, or critically endangered species/ communities. ❖ **Essential Species:** Supports populations of plant and/or animal species important for maintaining biological diversity. ❖ **Species Protection:** Supports plant and/or animal species at a critical stage in their life cycles or provides refuge during adverse conditions. ❖ **Waterbirds:** Regularly supports 20,000+ water birds. ❖ **Single Species of Water Birds:** Regularly supports 1% of the individuals in a population of one species or subspecies of water birds. ❖ **Indigenous Fish:** Supports a significant proportion of indigenous fish subspecies. ❖ **Multirole:** Is an essential food source for fishes, spawning ground, nursery and/or migration path. ❖ **Ecotourism:** Is an essential source of food and water resources, increased scope for recreation and ecotourism.
Removal from list	❖ Upon urgent **national interest** of contracting party (delete or restrict boundaries) ❖ Deletions/restrictions **to be compensated** by creating additional nature reserves in the same area or elsewhere. ❖ **No Ramsar Site** has ever been "deleted". Parties have only extremely rarely restricted the boundaries of a Site on this basis (success of Ramsar Convention).
Transboundary Sites	In these cases, **COP** allows the **establishment** of Ramsar Sites along with the **agreement of authorities on both sides** of the border to collaborate on-site management.
Montreux Record	❖ Register of Ramsar sites where **changes in ecological character** have **occurred**, are **occurring**, or are **likely to occur** as a result of technological developments, pollution or other human interference. ❖ Currently, **two wetlands of India are in Montreux record: Keoladeo National Park (Rajasthan)** and **Loktak Lake (Manipur).**
Contracting Parties (COP) to Ramsar Convention	❖ **Policy-making** organ. Meets every **3 years** at the Conference of the Contracting Parties (COP). ❖ **COP14 (2022):** Held in a hybrid format in Wuhan, China, and Geneva, Switzerland. **Wuhan Declaration** and **2025-2030 Global Strategic Framework for Wetlands Conservation** were adopted.
Responsibilities of the Contracting Parties	❖ To identify, and place suitable wetlands onto the Ramsar List. ❖ **Expected (not mandated) to manage their Ramsar Sites** to maintain their ecological character and retain their essential functions and values for future generations.
International Organisation Partners (IOPs)	**The Ramsar Convention works closely with six organisations**: ❖ Birdlife International ❖ International Union for Conservation of Nature (IUCN) ❖ International Water Management Institute (IWMI) ❖ Wetlands International ❖ World Wide Fund for Nature (WWF) ❖ International Wildfowl & Wetlands Trust (WWT)

Wetlands International

Global non-governmental organisation (NGO) to sustain and restore wetlands and their resources for people and biodiversity: includes research, advocacy, engagement with governments, corporate, etc.

LAKES

A lake is defined as "a body of water wholly or partly surrounded by land, containing permanent or temporary water." Lakes are typically larger than ponds, contain standing water, and can have connecting rivers and outlets.

Classification of Lakes

- **Temporary Lakes:** Formed after heavy rainfall in undulating terrain; water evaporates quickly.
  - **Example:** Temporary lakes in the Thar Desert post-monsoon.
- **Permanent Lakes:** Maintain consistent water levels with precipitation exceeding evaporation.
  - **Example:** Wular Lake (Jammu & Kashmir), Chilika Lake (Odisha).
- **Freshwater Lakes:** Contain freshwater, often fed by rivers with outflowing streams.
  - **Example:** Dal Lake (Jammu & Kashmir), Nainital Lake (Uttarakhand).
- **Saline Lakes:** High salt content due to rapid evaporation and lack of outlets.
  - **Example:** Great Salt Lake, Sambhar Salt Lake (Rajasthan).
- **Natural Lakes:** Result from tectonic activity, landslides, or lagoon formation.
  - **Example:** Vembanad Lake (Kerala), Pangong Lake (Ladakh).
- **Artificial Lakes:** Human-made for purposes like irrigation, hydropower, or water supply.
  - **Example:** Dhebar Lake (Rajasthan), Gobind Sagar (Himachal Pradesh).

Oligotrophic Vs Eutrophic Lakes

Parameters	Oligotrophic	Eutrophic
Definition	Few nutrients, low primary productivity	Abundant nutrients, high primary productivity
Water Parameters	Low turbidity, high oxygenation at depth, and clear water	High turbidity, low oxygenation at depth, and water often is brown or with greenish tint
Primary Producers	Low concentration	High concentration
Primary Productivity	<100mg carbon/m^2 a day	>100mg carbon/m^2 a day
Consumers	Many fishes at deep level	Few fishes at deep level
Microbes	Reduced Biomass	Increased Biomass

- **Phytoremediation:** Use of plants to remove contaminants from soil and water. Estuarine vegetation/ Mangroves/ other wetland vegetation carry out natural phytoremediation.
- **Phytoextraction/phytoaccumulation** is the accumulation of contaminants into the roots/leaves of plants/ above ground shoots. An aquatic weed named **water hyacinth** can cleanse water by taking toxic materials and many heavy metals from water.

ESTUARY

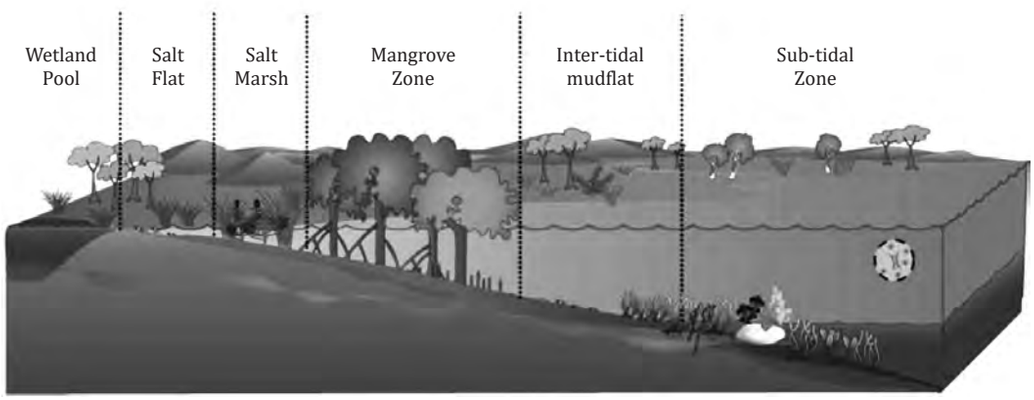


Fig. 10.17: Estuarine Ecosystem

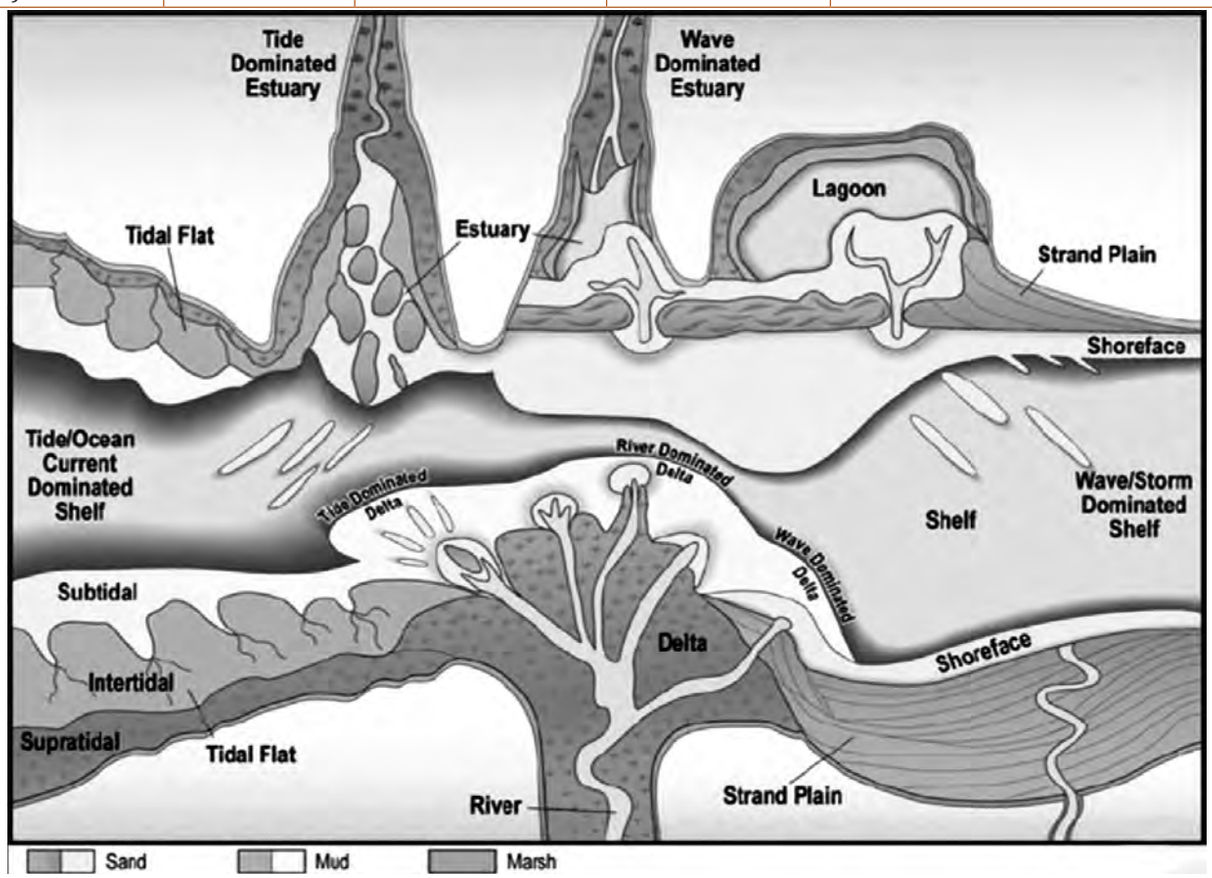
- **Definition: An estuary is a partially enclosed** coastal area of **brackish water** (salinity of **0-35** ppt) where a river or a stream opens into the sea (freshwater carrying fertile silt and runoff from the land mixes with salty seawater). Eg: **river mouths, coastal bays, tidal marshes, lagoons, and deltas**.
- Formed due to rise in sea level, movement of sand and sandbars, glacial processes, and tectonic processes. They are greatly influenced by tidal action and are periodically washed by seawater once or twice a day based on the number of tides.
- In some narrow estuaries, tidal bores are significant (damage to the estuarine ecology).

Ecological Importance of estuaries	❖ **Most productive** (more productive than other wetlands) water bodies in the world due to mixing of freshwater and saline water zones where marine organisms of both ecosystems meet. ❖ **Refuge from the Open Sea:** Due to minimal wave action, ideal for the survival of numerous aquatic species. Mangrove forests on the seaward side of an estuary act as a barrier for the coastal habitat to check the wind speed during cyclones and high-velocity landward winds. ❖ **Precipitation of Clay and Alluvium Particles:** Due to exposure to saline water. Mangroves trap suspended mud and sand carried by rivers which leads to delta formations around estuaries. ❖ **Nutrient Storage and Recycling:** Trap sediment; buffer between coastal catchments and the marine environment; absorb, trap and detoxify pollutants, **acting as a natural water filter**.
Economic Importance of Estuaries	❖ ~60% of the **world's population live** along estuaries and coasts. ❖ Rich in **natural resources**, including fisheries. ❖ Ideal locations for the construction of **ports and harbours**: Deep and well protected from marine transgressions.
Estuarine Vegetation	❖ Salinity and flooding determine the distribution (diversity and density) of organisms. ❖ **Diverse Habitats:** Mangroves, salt marshes, seagrass, mudflats etc. ❖ **Terrestrial Plants and Animals:** Wood storks, pelicans, coniferous and deciduous trees, and butterflies etc. ❖ **Aquatic Plants and Animals:** Sea turtles, sea lions, sea catfish, salt grasses, seagrass, bulrush, etc. ❖ **Phytoplankton:** Diatoms, dinoflagellates, green algae, and blue-green algae. ➢ Towards the seacoast: algae and seagrasses. ➢ Near the mouth of the rivers and deltas: mangrove forests.
Indian Estuarine Ecosystem	❖ 14 major, 44 medium, and 162 minor rivers drain into the sea ❖ **The majority of major estuaries occur on the east coast**. ❖ Estuaries on the west coast are smaller. ➢ **Serve as locations of major seaports.** E.g., Mormugao Port on the Zuari Estuary.
Threats Faced by the Estuarine Ecosystem	❖ **Changes in water flow** due to modifications of the catchments (E.g., Hooghly, Godavari, Pulicat, etc.). ❖ **Pollution** through industries, city sewage discharge, feeding stocked fish and prawns in pens (Chilika). ❖ **Navigation, dredging and shipping** (e.g. Hooghly). ❖ **Expansion of urban and rural settlements**, mining and industries, agriculture and dumping of solid wastes. ❖ **Intensive aquaculture** in pens and obstructing the migratory routes of fish and prawns (e.g., Chilika, Pulicat). ❖ **Biodiversity destruction** through prawn seed collection through small-meshed nets (e.g., Hooghly, Chilika, Pulicat). ❖ **Submergence** of catchment areas due to water level rise.

LAGOON

- Stretch of salt water separated from the sea by a low sandbank or coral reef. E.g: backwaters in Kerala where seawater flows inwards through a small inlet that is open towards the sea.
- The water is shallower and flows sluggishly compared to fast-flowing water in estuaries.

Name	Location	Type	Rivers Feeding It	Significance
Chilika Lake	Odisha	Brackish water lagoon	Daya and Bhargavi Rivers	Asia's largest brackish water lagoon, major stop for migratory birds, rich biodiversity.
Kaliveli Lake	Tamil Nadu	Wetland and lagoon	Local runoff and monsoonal rains	Ramsar Wetland site, known for birdlife, especially migratory birds.
Kayamkulam Kayal	Kerala	Lagoon	Pamba and Achankovil Rivers	Major lagoon in Kerala, important for fisheries and biodiversity.
Muthupet Lagoon	Tamil Nadu	Coastal lagoon	Koriayar and Pamaniyar	Known for mangrove forests, biodiversity, and importance to local fisheries.
Pulicat Lake	Tamil Nadu, Andhra Pradesh	Brackish water lagoon	Arani and Kalangi Rivers	One of India's largest lagoons, vital for migratory birds and fisheries.
Vembanad Lake (Punnamada Lake or Kochi Lake)	Kerala	Freshwater lake with lagoon features.	Meenachil, Pamba, Achankovil Rivers	Longest lake in Kerala, important for ecology, tourism, and aquatic life. It contains Kutannad-Rice Bowl of Kerala.



MANGROVES

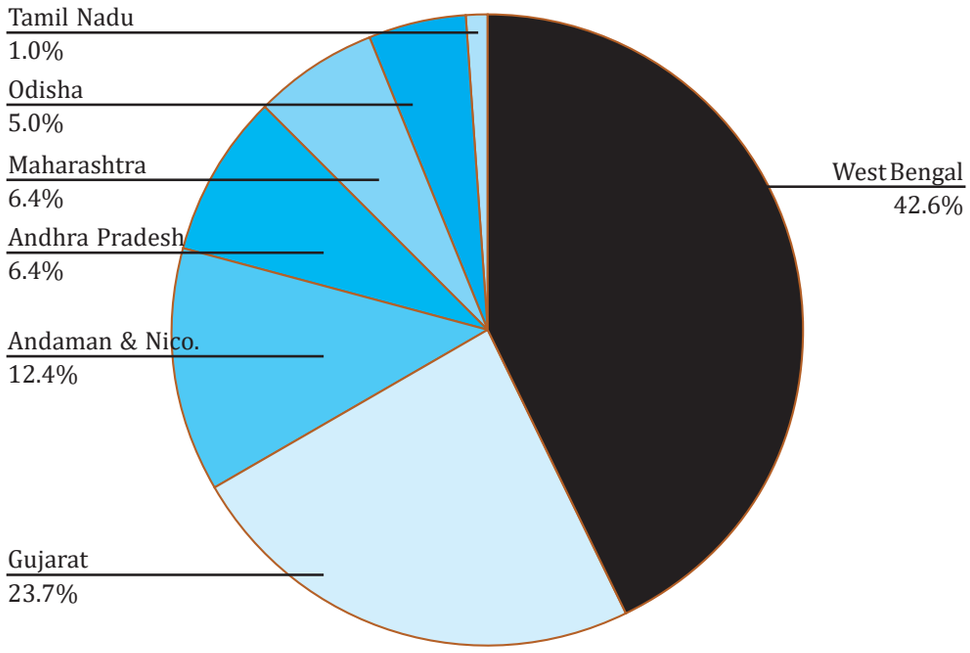
- Salt-tolerant (halophytes) evergreen shrubs or small trees (vary in height from 8 to 20 m) that represent a characteristic littoral (near the seashore) forest ecosystem. Some common mangrove trees include Red mangrove, Grey mangrove, and Rhizophora.
- Grow below the high water level of spring tides. Best locations are where abundant silt is brought down by rivers or on the backshore of accreting sandy beaches. Includes brackish waters of sheltered low-lying coasts, estuaries, mudflats, tidal creeks, backwaters, marshes and lagoons of tropical and subtropical regions.
- **Decreasing order of productivity:** Mangroves, grasslands, lakes, oceans.

Kharai camel: a breed found in India, capable of swimming upto 3km in seawater, grazes on mangroves.

Adaptations Exhibited by Mangroves

- **Succulent Leaves**
  - Thick leaves that store water and reduce water loss through **evapotranspiration**.
- **Sunken Stomata**
  - Stomata are embedded deeper in leaf tissue to minimize exposure to drying winds, reducing moisture loss.
- **Salt-Secreting Glands**
  - Specialized glands in leaves flush out excess salt, helping mangroves survive in saline environments.
- **Aerial Breathing Roots (Pneumatophores)**
  - Also known as blind roots, they extend above the soil or water surface, enabling mangroves to breathe in oxygen-deficient (anaerobic) conditions.
- **Viviparous Reproduction**
  - Seeds or embryos germinate while still attached to the parent tree, ensuring survival in harsh environments. After maturation, they fall into the water or soil and continue to grow.
- **Stilt and Prop Roots**
  - Fibrous roots that provide structural support, stabilizing the tree against strong wave action and tidal flows.
- **Buttresses**
  - Large, wide support roots at the base of shallow-rooted mangrove trees, enhancing stability.
- **Adventitious Roots**
  - These roots, including **prop and stilt roots**, emerge from the trunk above ground, supporting the tree in soft, waterlogged soil.
- **Complex Root System**
  - **The intricate root system combats:**
    - **Strong wave action**
    - **Diurnal tidal inundation**
    - **Respiration challenges** in oxygen-poor soil.
- **Species-Specific Root Adaptations**
  - **Arching Prop Roots:** Found in species like *Rhizophora*, extending into water for stability.
  - **Vertical Pneumatophores:** Seen in species like *Avicennia*, protruding vertically from the mud for oxygen intake.

Mangroves in India



The **ISFR 2023** indicates a decrease of 7.43 sq km in mangrove cover compared to the previous assessment in 2021.While some states like **Andhra Pradesh and Maharashtra have reported increases** in mangrove cover, others, notably **Gujarat and Andaman & Nicobar Islands** have experienced declines.

The largest increase in mangrove cover in terms of area has been observed in Andhra Pradesh,largest decline in Gujarat.

Mangroves of Sundarbans

- The name is derived from the Sundari mangrove tree.
- Largest single block of tidal halophytic mangroves in the world.
- Eco-geography is dependent on the tidal effect: deposits silt back on the channels, raising the bed and forming new islands and creeks.
- **Only mangrove forests are inhabited by the tigers.**
- **Major fauna:** Royal Bengal tiger (EN), saltwater crocodile (LC), river terrapin, olive ridley turtle (VU), Ganges river dolphin (EN), hawksbill turtle, mangrove horseshoe crab, etc.

Mangrove Forests on the East Coast

- **Mangroves of Bhitarkanika (Orissa):** 2nd largest in India, cover the area of Brahmani and Baitarani river deltas.
- Godavari-Krishna deltaic regions of Andhra Pradesh.
- **Pichavaram** and **Vedaranyam** are degraded due to aquaculture ponds and salt pans.

On the west coast of India

- Mostly **scrubby** (stunted) and **degraded,** occur along the intertidal region of estuaries and creeks in **Maharashtra, Goa, and Karnataka**.
- **Kerala:** very sparse and thin.
- **Gujarat** (north-west coast): Gulf of Kutch and the Kori Creek region (paleo delta of the Indus River (once upon a time, it was part of the Indus delta).

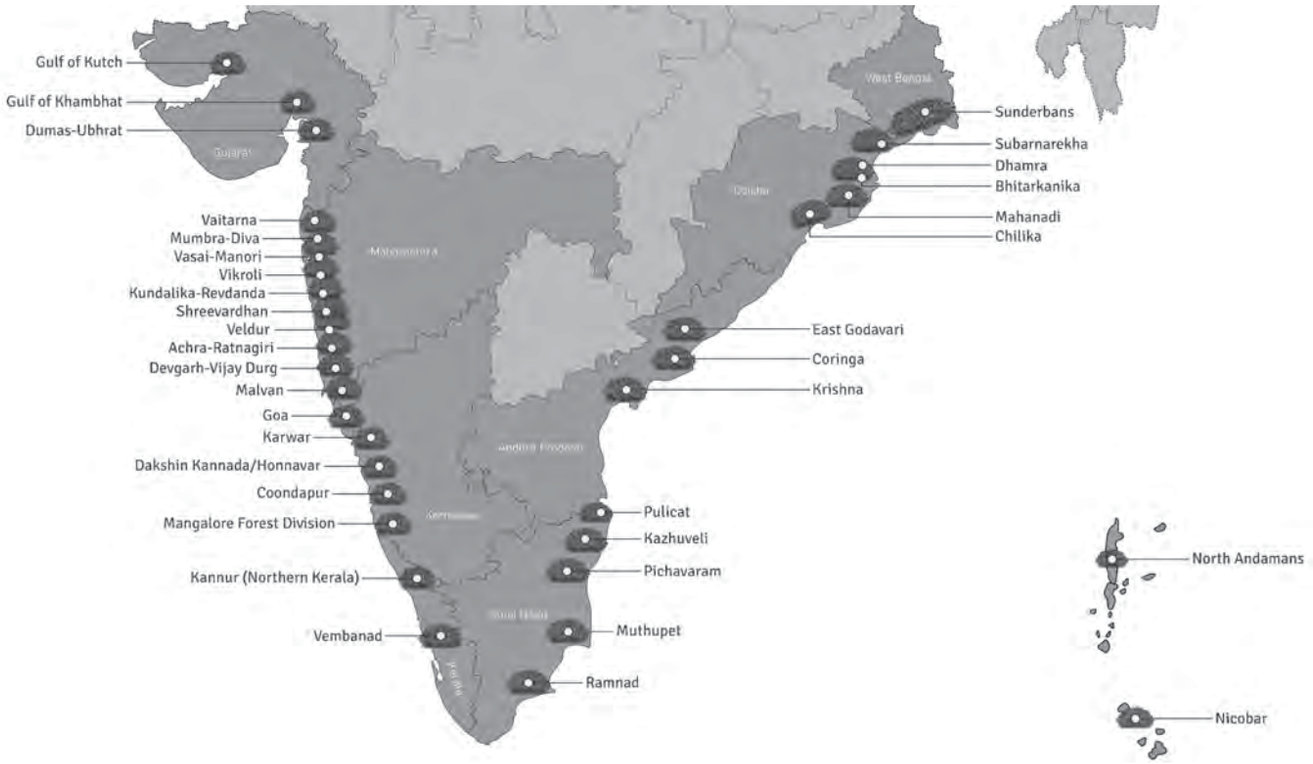


Fig. 10.18: Mangroves in India

Global Status

- The latest Global Mangrove Watch (GMW v4.0) map provides a sixfold improvement in spatial resolution for global mangrove mapping. It maps 147,256 km^2 of mangroves (2020) and includes six new territories in its dataset.
- Southeast Asia contains about one-third of the world's mangroves, with Indonesia alone contributing 21% of the total global mangrove area.
- **>40 per cent of the total area in just four countries:** Indonesia (19%), Brazil (9%), Nigeria (7%) and Mexico (6%).
- **Confined to the tropics and subtropics** (intertidal regions between latitudes 24° N and 38° S) as adaptive mechanisms are energy-intensive and require high solar radiation.

Importance of Mangroves

- **Highly Productive Ecosystems:**
  - Mangroves are among the most productive ecosystems, supporting a rich biodiversity.
  - They provide food, shelter, and breeding grounds for numerous terrestrial and aquatic species.
- **Coastal Protection:**
  - Mangroves protect coastal areas from tsunamis, storm surges caused by cyclones, and soil erosion.
  - Their complex root systems stabilize shorelines and reduce wave energy.
- **Land Accretion:**
  - They slow down water flow, promoting sediment deposition and acting as zones of land accretion.
- **Flood Moderation:**
  - Mangroves reduce the inundation of coastal lowlands by moderating monsoonal tidal floods.
- **Riparian Buffer:**
  - Mangroves act as natural riparian buffers along coastal and estuarine zones.
  - They filter pollutants, including heavy metals, from surface runoff and prevent them from entering water bodies.
  - Enhance natural nutrient recycling and act as carbon sinks, aiding in climate regulation.
- **Habitat for Aquatic Life:**
  - Provide a safe and favorable environment for breeding, spawning, and rearing various fish and marine species.
- **Livelihood Support:**
  - Mangroves are essential for the livelihood of coastal communities.
  - Communities derive resources such as honey, tannins, wax, firewood, medicinal plants, edible plants, and fish from mangroves.

Threats to Mangroves

Threat	Description	Consequences
Aquaculture, Agriculture, and Salt Ponds	Nutrient-rich mangroves cleared for shrimp farming, mariculture, agriculture, and salt ponds.	Chemicals enter the food chain; eutrophication due to excess nutrients.
Coastal Development and Lumbering	Exploitation for charcoal and wood products; conversion of wetlands for coastal development projects.	Habitat loss, reduced biodiversity, imbalance in fresh and saltwater, and increased climate vulnerability.
Climate Change	Mangroves as carbon sinks release stored carbon when deforested, compounding the climate crisis.	Rising sea levels damage mangroves, causing habitat loss and reduced resilience to saltwater intrusion.
Replantation Limitations	Focused on a single species instead of a diverse mix; mangroves have lower species richness than tropical forests.	Reforestation/afforestation fails to fully restore lost habitats or ecosystem functions.

Biodiversity is the variety of life on Earth, encompassing the diversity of species, ecosystems, and genetic diversity within species.

TYPES OF BIODIVERSITY

- **Genetic Diversity:** encompasses the **variety of genetic characteristics within a species**. For example, in Homo sapiens, diverse genetic characteristics are evident among different ethnic groups, such as Chinese, Indian, and African. This diversity is crucial for species adaptation to changing environments, ensuring survival through significant environmental changes.
- **Species Diversity:** A measure of the diversity within an ecological community, considering both species richness and the evenness of their distribution.
- **Ecological Diversity:** Refers to the variety of habitats within a region.
  - For example, India exhibits significant ecological diversity with deserts, rainforests, mangroves, coral reefs, wetlands, estuaries, and alpine meadows.

MEASURES OF BIODIVERSITY

Species Richness

A measure of the **number of different species present** in a particular ecological community, ecosystem, or area.

- It **quantifies the diversity of species** and provides information about the variety of life within a specific habitat.
- **Tropical rainforests** in the terrestrial ecosystem and **coral reefs** in the marine ecosystem have the highest degree of species richness.

Species Evenness

A measure of **how evenly individuals are distributed among the different species** in a given area.

- It **assesses the balance in the abundance of each species**, indicating whether one or a few species dominate the ecosystem or if the distribution of individuals is more uniform across various species.

ALPHA, BETA AND GAMMA DIVERSITY

R.H. Whittaker introduced three levels of biodiversity to assess variations within and across ecosystems: alpha, beta, and gamma diversity.

Alpha Diversity (Within-Community Diversity)

- **Definition:** Measures species diversity within a specific area, community, or ecosystem. It is measured by Shannon Index or Simpson's Diversity Index.
- **Focus:** Local diversity.
- **Indicators:** Species richness and species evenness.
- **Example:**
  - A forest patch has **10 species** of plants.
  - The alpha diversity of this patch is **10 species**.

Beta Diversity (Between-Community Diversity)

- **Definition:** Measures the change in species composition between two ecosystems or communities.
- **Focus:** Comparison of species diversity across habitats or ecosystems.

Gamma Diversity (Regional Diversity)

- **Definition:** Measures overall species diversity in a large geographical area (e.g., landscape or region) encompassing multiple ecosystems.
- **Focus:** Total diversity of all ecosystems combined.
- **Example:**
  - A landscape with three ecosystems (forest, grassland, and wetland):
    - Forest: 10 species
    - Grassland: 12 species
    - Wetland: 8 species
    - Total distinct species (removing overlap): 25 species
    - Gamma diversity is 25 species.

SPECIATION

Speciation is the process by which new species arise from a single ancestral species over time. There are several types of speciation, each driven by different mechanisms of reproductive isolation:

Type of Speciation

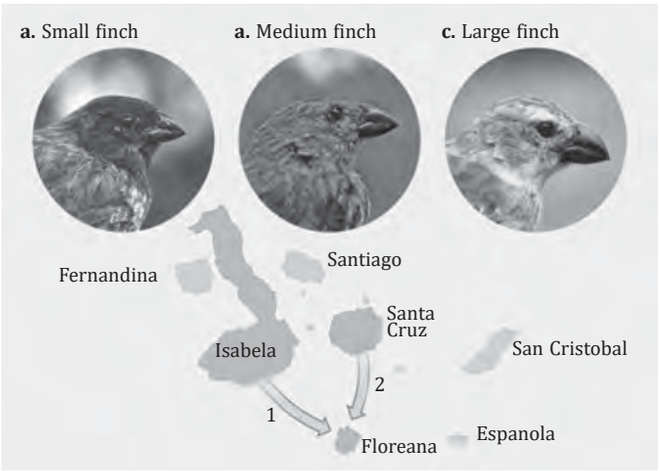


Fig. 10.19: Allopatric Speciation among Darwin Finches

Type of Speciation	Mechanism	Example	Key Features
Allopatric Speciation	Geographic isolation through physical barriers (e.g., mountains, rivers).	**Darwin's Finches:** Geographical separation in the Galápagos Islands.	Genetic divergence due to mutation, genetic drift, and natural selection.
Sympatric Speciation	Occurs without geographic isolation, often through polyploidy, habitat differentiation, or disruptive selection. Polyploidy refers to the condition in which an organism has more than two complete sets of chromosomes in its cells.	**Apple Maggot Fly:** Evolved to specialize on different host plants in the same area.	New species arise within the same geographic area.

Parapatric Speciation	Limited gene flow between populations along a geographical gradient.	**Ensatina Salamanders:** Ring species where adjacent populations interbreed, but distant ones do not.	Genetic differences accumulate despite physical proximity.
Peripatric Speciation	Small, isolated populations on the periphery of a species' range evolve into new species.	**Anolis Lizards:** Island populations in the Caribbean.	Rapid evolution and genetic drift in small founder populations.
Adaptive Radiation	Rapid diversification into multiple species to exploit different ecological niches.	**Galápagos Finches:** Diversified with various beak shapes to exploit different food resources.	Single ancestral species gives rise to multiple species adapted to diverse niches.

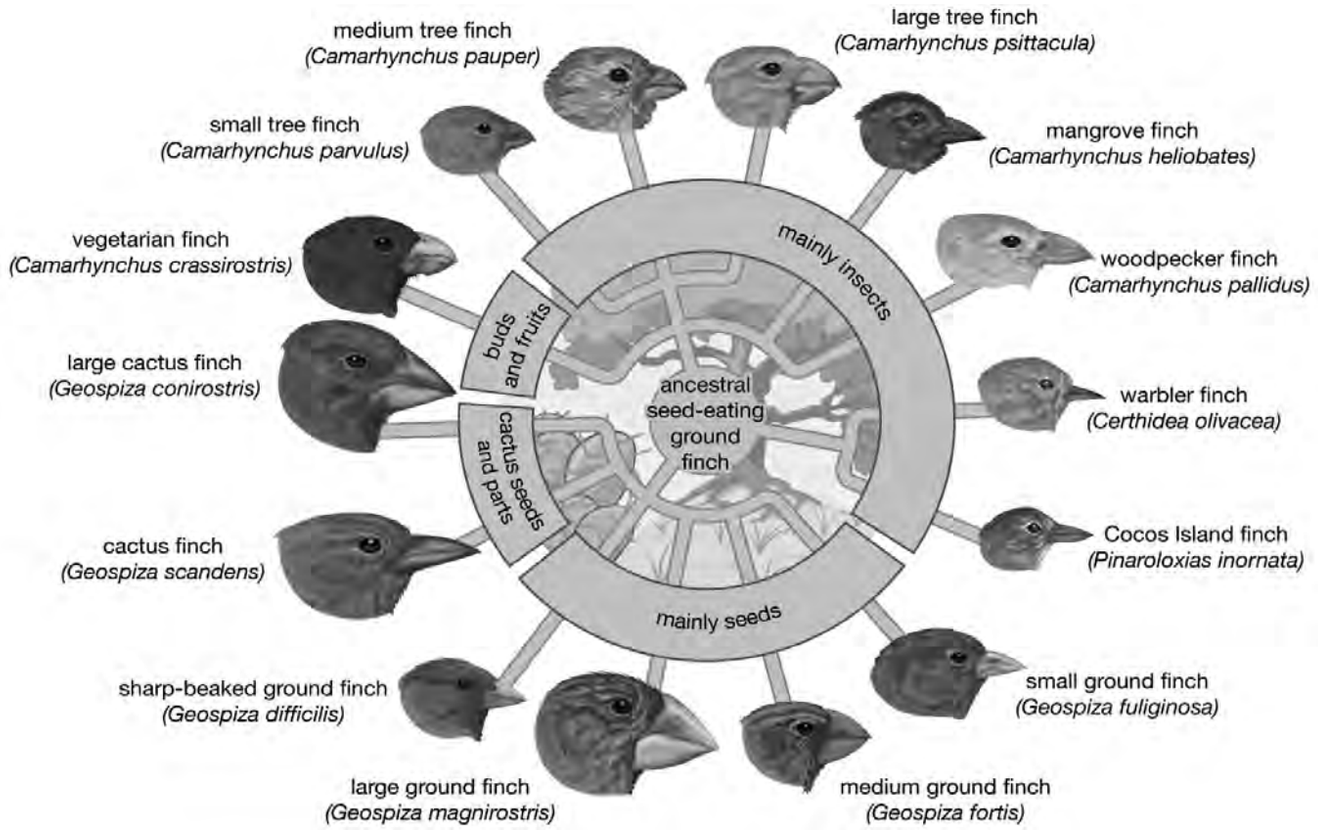


Fig. 10.20: Adaptive Radiation in Galapagos Finches

SPECIES CATEGORIES IN ECOSYSTEM CONSERVATION

Ecosystem conservation relies on the unique roles of various species. Below are key categories with examples from India, highlighting their ecological importance and geographical locations:

Keystone Species

Every ecosystem has certain species that are critical to the survival of the other species in the system. The keystone species could be a huge predator or an unassuming plant, but without them the ecosystem may not survive.

- **Examples:**
  - **Asiatic Lion:** Found in the Gir Forest, Gujarat, it regulates herbivore populations, ensuring vegetation sustainability.
  - **Dhole (Indian Wild Dog):** Inhabits the Western and Eastern Ghats, controlling prey populations to maintain ecological stability.

- **Fiddler Crab:** Found in the Sundarbans and East Coast mangroves, it aerates sediments and supports nutrient cycling.
- **Beavers:** Beavers are one of the few animals that modify their habitat. Beavers build watertight dams made of woven sticks, reeds, branches and saplings caulked together with mud and rocks. The dams form slow-moving ponds that reduce stream erosion and provide brand new habitat for small fish and other aquatic wildlife. They are keystone species in North America.
- **Other examples:** Sharks, Bees, Mangroves

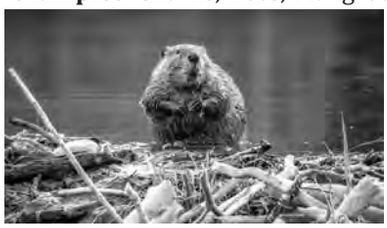


Fig. 10.21: Beaver Building a Dam

Indicator Species

These species reflect the overall health of ecosystems and act as early warning signs of environmental changes.

- **Examples:**
  - **Frogs and Amphibians:** Common in wetlands and forests across India, they are sensitive to water quality and habitat changes.
  - **Mahseer Fish:** Found in Himalayan and Western Ghats rivers, they indicate freshwater ecosystem health.
  - **Coral Reefs:** Located in the Gulf of Mannar and Lakshadweep, they signal marine ecosystem health.

Endemic Species

Native and restricted to specific geographic areas, these species represent unique biodiversity and require focused conservation efforts.

- **Examples:**
  - **Lion-tailed Macaque:** Found in the Western Ghats, critical for forest ecosystem preservation.
  - **Sangai Deer:** Unique to Loktak Lake, Manipur, it represents wetland ecosystem health.
  - **Beddome's Toad:** Restricted to the Western Ghats, reflecting microhabitat specificity.

Invasive Alien Species

Non-native species introduced to ecosystems often disrupt local biodiversity and outcompete native species.

- **Examples:**
  - **Water Hyacinth:** Common in wetlands across India, clogs waterways, depletes oxygen, and impacts aquatic species.
  - **Prosopis Juliflora:** Found in Rajasthan, Tamil Nadu, and Andhra Pradesh, it alters soil chemistry and reduces native vegetation.
  - **African Catfish:** Introduced in Indian rivers and lakes, it competes with and threatens native fish populations.

Fig. 10.22: Water Hyacinth

Flagship Species

These charismatic species are used to mobilize public and financial support for conservation efforts.

- **Examples:**
  - **Indian Elephant:** Inhabits forests of South, Northeast, and Central India, driving forest conservation.
  - **Great Indian Bustard:** Found in Rajasthan and Gujarat, it advocates for arid grassland conservation. It was the **mascot of CMS COP-13 held in Gandhinagar in 2020.**

Fig. 10.23: Great Indian Bustard

  - **Sangai Deer:** Promotes wetland conservation in Loktak Lake, Manipur.

Umbrella Species

Protecting these species aids in the conservation of their habitats and co-inhabitant species.

- **Examples:**
  - **Bengal Tiger:** Found in the Sundarbans, Western Ghats, and Terai grasslands, its conservation protects vast ecosystems.
  - **Black-necked Crane:** Found in high-altitude wetlands of Arunachal Pradesh, aiding in alpine wetland protection.
  - **Indian Rhino:** Inhabits Kaziranga National Park, Assam, securing wetland biodiversity.

Foundational Species

These species shape and maintain ecosystems, providing structure and essential resources for other organisms.

- **Examples:**
  - **Mangroves**: Located in the Sundarbans, they prevent coastal erosion and provide nurseries for fish.
  - **Sacred Fig (Peepal Tree)**: Found across urban and rural landscapes, it supports pollinators and provides oxygen.
  - **Shola Grasslands**: Found in the Western Ghats, crucial for regulating hydrology and supporting endemic species.

Fig. 10.24: Mangroves

Fig. 10.25: Shola Grasslands and Forests of Nilgiri

HOMEOSTASIS IN ORGANISMS

Homeostasis refers to the ability of organisms to maintain a stable internal equilibrium despite changes in the external environment. It is achieved through various physiological and behavioral functions, ensuring survival under different conditions.

Physiological Homeostasis

- **Temperature Regulation:**
  - **Humans:** Sweating to cool down in hot weather and shivering to generate heat in cold climates.
  - **Dogs:** Panting to regulate body temperature.
- **Osmoregulation:**
  - **Fish:** Marine fish excrete concentrated urine to conserve water, while freshwater fish excrete diluted urine to remove excess water.
- **Blood Glucose Levels:**
  - **Humans:** Insulin lowers blood glucose after a meal; glucagon raises it during fasting.

Behavioral Homeostasis

- **Migration:**
  - **Siberian Cranes:** Migrate to India during harsh winters for favorable conditions.
  - **Bar-headed Geese:** Fly over the Himalayas to warmer regions.
- **Thermal Regulation:**
  - **Desert Lizards:** Bask in the sun to warm up and seek shade to cool down.
  - **Elephants:** Use their large ears to dissipate heat and mud baths to cool down.

Adaptations in Extreme Conditions

- **Hibernation (Cold):**
  - **Polar Bears**: Enter a dormant state during winters to conserve energy.
  - **Bats:** Hibernate in caves to survive food scarcity during winter.
- **Aestivation (Heat and Dry):**
  - **Lungfish:** Survive drought by burrowing into mud and reducing metabolic activity.
  - **Snails:** Seal their shells and remain inactive during extreme heat.
- **Diapause (Unfavorable Growth Conditions):**
  - **Zooplankton**: Pause development during periods of food scarcity or temperature extremes.

Plant Examples

- **Stomatal Regulation:**
  - **Cacti:** Open stomata at night (CAM photosynthesis) to minimize water loss.
  - **Rice Plants:** Close stomata during midday heat to prevent excessive water loss.
- **Seed Dormancy:**
  - **Acacia:** Produces stress-resistant seeds that sprout after rainfall in deserts.
  - **Lotus:** Seeds can remain dormant for centuries and germinate when conditions improve.

Microbial Examples

- **Spore Formation:**
  - **Bacteria (Bacillus):** Form endospores to survive extreme heat and desiccation.
  - **Fungi:** Produce spores to endure unfavorable conditions like drought or lack of nutrients.

BIODIVERSITY DYNAMICS: ENDEMISM, BIOPROSPECTING, AND BIOPIRACY

- Endemism refers to the **ecological condition where a species is exclusively found in a specific defined geographic area**, such as an island, nation, country, or distinct habitat.

- If organisms native to a particular place are also found in other locations, they are not considered endemic. For example - **Red Sanders**, **sandalwood, peepal tree, banyan tree and neem tree.**
- The contrasting concept to endemism is a cosmopolitan distribution, where a species is widespread and found across various regions or habitats.

Native Species Across the World

The main difference between native and endemic species is that native species can be found in multiple areas, while endemic species are only found in a specific areas.

Country	Important Native Animals	Important Native Plants	Superfoods/Fruits/Vegetables/ Produce
India	Royal Bengal Tiger, Asian Elephant, Indian Peacock, Lion-tailed Macaque	Banyan Tree, Indian Sandalwood, Neem	Moringa, Mango (Alphonso), Banana, Turmeric, Cardamom
Brazil	Jaguar, Giant Anteater, Capybara, Amazon River Dolphin	Açaí Palm, Brazil Nut Tree, Rubber Tree	Açaí Berry, Pineapple, Guava, Brazil Nut
Indonesia	Komodo Dragon, Orangutan, Bali Starling	Clove Tree, Teak, Mangroves	Nutmeg, Clove, Durian, Coffee
Madagascar	Indri, Ring-tailed Lemur, Tomato Frog	Baobab, Traveller's Palm	Vanilla, Lychee, Baobab Fruit
Australia	Kangaroo, Koala, Emu, Platypus	Eucalyptus, Wattle, Waratah	Macadamia Nut, Kakadu Plum, Wattleseed
South Africa	African Elephant, Cheetah, White Rhinoceros, Meerkat	Baobab, Protea, Aloe	Marula Fruit, Rooibos Tea, Baobab Powder
China	Giant Panda, Red Panda, Golden Snub-nosed Monkey	Bamboo, Ginkgo Biloba, Chinese Tea Plant	Lychee, Soybean, Goji Berry
USA	American Bison, Bald Eagle, Grizzly Bear	Giant Sequoia, Joshua Tree, Prairie Grass	Corn, Cranberries, Almonds, Avocados
New Zealand (RAS 2013)	Kiwi, Kakapo, Tuatara	Pohutukawa, Kauri Tree, Manuka	Kiwi Fruit, Manuka Honey
Mexico	Axolotl, Jaguarundi, Mexican Gray Wolf	Agave, Nopal (Prickly Pear Cactus)	Avocado, Tomato, Vanilla, Maize (Corn)

Endemic Species of the World

Country	Endemic Animal Species	Endemic Plant Species
India	Asiatic Lion (Gujarat), Lion-tailed Macaque (Western Ghats), Kashmir Stag, Nilgiri Tahr	Nilgiri Mountain Holly, Indian Rosewood, Beddome's Oak, Andaman and Nicobar Islands Palm
Australia	Platypus, Koala, Wombat, Tasmanian Devil, Short-beaked Echidna	Eucalyptus (various species), Banksia, Waratah, Kangaroo Paw
Brazil	Golden lancehead pit viper (Isla da Queimada Grande), Brazilian Merganser, Uakari Monkey	Brazil Nut Tree, Pau Brasil (Brazilwood), Cacto do Sertão
Madagascar	Indri , Aye-aye, Fossa, Ring-tailed Lemur	Baobab, Traveller's Palm, Madagascar Periwinkle
New Zealand	Kiwi, Kakapo, Tuatara, New Zealand Sea Lion	Pohutukawa, Manuka, Kauri Tree
South Africa	Cape Mountain Zebra, Bontebok, Dung Beetle (Cercyon), Golden Mole	Protea (national flower), Silver Tree, Cycad

China	Giant Panda, Chinese Alligator, Golden Snub-nosed Monkey, Tibetan Antelope	Chinese Ginseng, Chinese Yew, Wuling Mountain Cucumber
Mexico	Axolotl, Mexican Gray Wolf, Mexican Beaded Lizard	Mexican Marigold, Nopal (Prickly Pear Cactus), Mexican Fan Palm
Indonesia	Komodo Dragon, Javan Rhinoceros, Sumatran Tiger	Rafflesia, Indonesian Orchid, Clove (native to the Moluccas)
USA	California Condor, Hawaiian Monk Seal, San Joaquin Kit Fox, Bison (Yellowstone)	Joshua Tree, Giant Sequoia, California Poppy, Saguaro Cactus

Bioprospecting

- Exploration of biodiversity to discover commercially valuable genetic resources and biochemicals.
- Involves deriving economically important products by exploring molecular, genetic, and species diversity in nations rich in biodiversity.

Biopiracy

- Unauthorized taking of genetic resources and traditional knowledge from biodiverse developing countries.
- Stolen traditional knowledge benefits non-indigenous entities through products or patents without compensating the indigenous people.
- **Regulation:** Addressed by the **Nagoya Protocol** to the **Convention on Biological Diversity**, ensuring fair and equitable sharing of benefits from using traditional knowledge and genetic resources.

BIODIVERSITY DISTRIBUTION PATTERNS

Latitudinal Gradient

- Biodiversity is richer in tropical regions (low latitudes) compared to temperate or polar regions (high latitudes).
- **Example:** The Amazon rainforest {Lungs of Planet Earth (RAS 2013)}, located near the equator, hosts millions of species, making it one of the most biodiverse ecosystems on Earth, whereas the Arctic regions have significantly fewer species.

Altitudinal Gradient

- Biodiversity typically declines as altitude increases because of harsher environmental conditions at higher elevations.
- **Example:** In the Himalayas, lower altitudes support lush forests with diverse flora and fauna, while higher altitudes have sparse vegetation and fewer species like snow leopards or yaks.

BIODIVERSITY OF INDIA

- **Mega-Diverse Country:** India is classified as a mega-diverse country, characterized by extraordinarily rich biodiversity that supports a significant portion of the Earth's species. These countries, constituting only about 10% of the Earth's surface, house around 70% of terrestrial biological diversity.
- **UN-identified Mega-Diverse Countries:** According to the World Conservation Monitoring Centre (WCMC) of the United Nations Environment Program (UNEP), **India is among 17 megadiverse countries**, alongside Australia, Brazil, China, and others.
- **Biodiversity Statistics:** India possesses 25.17% of its area under forest and tree cover. Despite occupying only 2.4% of the global land area, **India harbors nearly 7-8% of recorded species** while supporting almost 18% of the human population.
- **Biogeographic Diversity:** India represents two realms, five biomes, ten biogeographic zones, and twenty-five biogeographic provinces. It is home to 91,000 species of animals and 45,500 species of plants.
- **Endemism:** A notable feature is the **high endemism**, with 12.6% of mammals, 4.5% of birds, 45.8% of reptiles, 55.8% of amphibians, and 33% of Indian plants being endemic to the region.
- **Biogeographic Realms:** Large spatial regions where ecosystems exhibit broadly similar biota or biological communities. Globally, there are eight recognized terrestrial biogeographic realms. The Indian region is situated in two biogeographic realms:
  - **Himalayan Region:** Represented by the Palearctic Realm. The Himalayan Range is very rich in species diversity because it is a confluence of different biogeographical zones.
  - **Rest of the Subcontinent:** Represented by the Malayan Realm.
- **Biomes:** Main groups of plants and animals in areas with specific climate patterns, depicting interactions among animals, vegetation, and soil. **5 Indian Biomes:** Tropical Humid Forests, Tropical Deciduous Forests (Monsoon Forests), Warm deserts and semi-deserts, Coniferous forests, Alpine meadows.
- **Biogeographic Provinces:** Ecosystemic or biotic subdivisions of realms. **India is divided into 25 biogeographic provinces.**

- **Biogeography:** Study of the geographical distribution of plants and animals. **10 Biogeographic Zones in India:** Trans Himalaya, The Himalaya, The Indian Desert, The Semi-Arid, The Western Ghats, The Deccan Peninsula, The Gangetic Plain, The Coasts, Northeast India, Islands.

Biodiversity Hotspots (RAS 2013)

- Term coined by British biologist **Norman Myers**; adopted by Conservation International (CI).

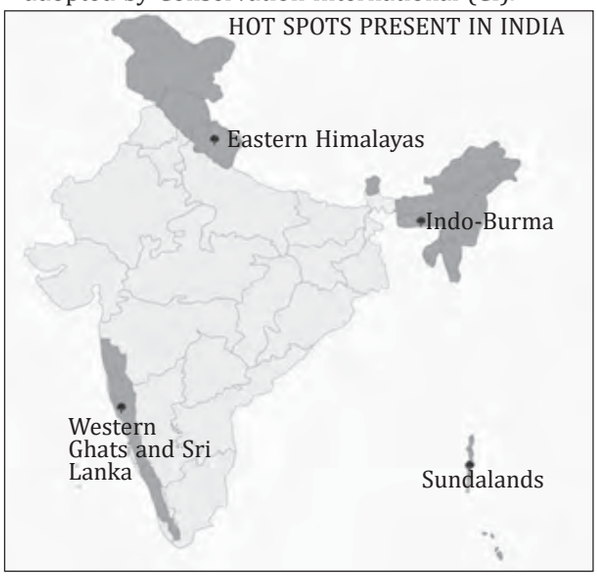


Fig. 10.26: Biodiversity Hotspot in India

- **Conservation International Criteria for Hotspots.**
  - **Endemism-** Must have at least 1,500 species of vascular plants as endemics (> 0.5% of the world's total).
  - **Threat perception-** Must have lost at least 70% of its original habitat (30% or less of its original natural vegetation).
- **Number of Hotspots:** Initially, 25 hotspots were identified in 1999; currently, **36 hotspots cover 2.5% of the Earth's land surface. Of 36 India contains 4: Himalaya, Indo-Burma, Western Ghats-Sri Lanka, and Sundaland**
- **Significance:** Hotspots support over half of the world's plant species as endemics and nearly 43% of bird, mammal, reptile, and amphibian species as endemics.
- **India's Biodiversity Hotspots:**
  - **Himalaya:** Includes the entire Indian Himalayan region and neighbouring countries.
  - **Indo-Burma:** Covers North-Eastern India, the Andaman Islands, and several Southeast Asian countries.
  - **Sundalands:** Encompasses Nicobar Islands, Indonesia, Malaysia, Singapore, Brunei, and the Philippines.
  - **Western Ghats and Sri Lanka.**

Hope Spots

- Marine Protected Areas requiring special protection due to wildlife and significant underwater habitats.
- **Initiative:** Joint effort by **Mission Blue (a global coalition) and IUCN.**
- **India's Hope Spots:** Lakshadweep Islands and Andaman Nicobar Islands.

LOSS OF BIODIVERSITY

Type	Scale	Description	Example
Alpha (α)	Local	Within a habitat	Forest patch
Beta (β)	Between habitats	Species turnover between habitats	Forest vs. grassland
Gamma (γ)	Regional	Overall diversity of a landscape	Western Ghats region

- **Mass Extinctions:** A mass extinction event is a period in Earth's history when biodiversity drops sharply, with about 75% or more of all species going extinct within less than 2.8 million years — a geologically brief span.
  - Five episodes of mass extinctions occurred over more than 3 billion years.
  - The **ongoing Sixth Extinction (anthropogenic)** is estimated to be 100 to 1,000 times faster than pre-human times.

Causes Behind Biodiversity Loss

- **Natural Ecological Disturbances**
  - Weather, wildfires, floods, and volcanic eruptions cause temporary ecosystem changes.
  - Natural disturbances are part of ecological succession and are usually adapted by ecosystems.
- **Evil Quartet - Major Causes**
  - **Habitat Loss:** Reduction in space for species, often due to activities like deforestation and urbanization.
  - **Overexploitation:** Excessive use of natural resources, leading to depletion of species like fish and trees.
  - **Alien Species:** Introduction of non-native species that disrupt ecosystems.
  - **Secondary Extinction:** Extinction of one species triggers the loss of others dependent on it.
- **WWF's Six Key Threats:** Agriculture, hunting, logging, pollution, invasive species, and climate change contribute to biodiversity loss.
- **Habitat Loss and Fragmentation**
  - **Habitat Loss:** Reduction in space where species can survive, notable in tropical rainforests.
  - **Habitat Fragmentation:** Large habitats are transformed into smaller, isolated patches, leading to inbreeding and local extinction risks.
  - **Barrier Effect:** Increases the risk of inbreeding and limits gene pool diversity.
- **Alien Species Invasions**
  - Non-native species spreading rapidly and threatening native biodiversity.
  - Invasive species are a significant cause of biodiversity loss.
- **Over-exploitation:** Excessive use of natural resources, endangering species like marine fish, whales, and trees.
- **Species Extinction:** Traits leading to increased species' vulnerability to extinction include rarity, poor dispersal ability, high trophic status, and low adult survival rates.
- **Genetically Modified Organisms (GMOs)**
  - Genetic modification can lead to dominant GMO species that reduce biodiversity.
  - Unintended effects and cross-pollination can contribute to biodiversity loss.
- **Trade in Wildlife**
  - Unsustainable harvest and trade threaten wildlife and biodiversity.
  - Illegal wildlife trade contributes to habitat destruction and disease spread.
- **Pollution and Climate Change**
  - Ocean acidification affects marine biodiversity.
  - Climate change influences ecosystem health, affecting the distribution of species

Consequences of Loss of Biodiversity

- **Affects Livelihood**
  - Changes in ecosystem services affect livelihoods, income, and migration.
  - Loss of biodiversity may limit the discovery of potential treatments for diseases.
- **Food and Nutritional Security Crisis**
  - Biodiversity influences world food production and sustainable soil productivity.
  - Nutrition and biodiversity are linked, impacting global nutritional status.
- **Human-Animal Conflict**
  - Interaction between wild animals and humans causing negative impacts.
  - Causes include human encroachment, land use changes, habitat loss, and climate change.
  - Impacts include crop and property damage, livestock depredation, injuries, and deaths.
- **Preventive and Mitigation Strategies for Human-Animal Conflict:** Artificial and natural barriers, guarding, alternative livestock husbandry practices, relocation, waste management, and community-based management.
- **Culling - Conservation or Biodiversity Loss**
  - Natural Culling: Natural processes like starvation, disease, and predation control populations.
  - Controlled Culling by Humans: Necessary for managing wildlife populations due to human-animal conflict and threats to life and livelihood.
- **Increased Zoonoses due to Habitat Loss**
  - Zoonotic diseases (transmitted from animals to humans) thrive in environments with changes in ecosystems and biodiversity loss.
  - Zoonoses are closely linked with ecosystem health, and habitat loss facilitates spillover from wildlife to humans.

- **Adverse Changes to Biotic Interactions**
  - Diminishing niches and roles of species in ecosystems lead to adverse changes.
  - Sudden declines in species can significantly alter ecosystem structure and functions.

Consequences of Butterfly Population Decline
Reduced Pollination: Many plants depend on butterflies for pollination. A decline could negatively impact their reproduction and survival.

Impact on Food Chains: Butterflies serve as prey for species like wasps, spiders, and birds. Their decline could disrupt these populations.

IN SITU CONSERVATION

In situ conservation refers to the conservation of species in their natural habitats, allowing them to continue their evolutionary processes. It contrasts with ex situ conservation, where species are conserved outside their natural environment (e.g., in zoos or botanical gardens). In situ conservation ensures the survival of species by protecting the ecosystem, allowing species to maintain their roles within their natural environment.

Methods

- **Protected Areas:** Establishing national parks, wildlife sanctuaries, and biosphere reserves to protect species in their habitats.
- **Community Involvement:** Engaging local communities in conservation efforts by providing education and sustainable livelihood alternatives.
- **Legislation:** Enforcing laws that protect endangered species and their habitats, such as the Wildlife Protection Act, 1972 in India.
- **Restoration Projects:** Rehabilitating degraded ecosystems to restore the natural habitat for species.

Biosphere Reserves

- Large protected areas involving terrestrial, marine, and coastal ecosystems.
- Few biosphere reserves are recognised under UNESCO's Man and the Biosphere Programme.
- Learning places for sustainable development.
- Managed under the sovereign jurisdiction of countries.
- The most important strategy for the conservation of biodiversity together with traditional human life.
- **Seville Strategy**
  - Adopted in 1995, emphasizing a community-based approach for biosphere reserves.
  - Includes social, cultural, spiritual, and economic needs alongside scientific research.
- **Core Buffer Strategy**
  - **Core Area:** Strictly protected with no human activity.
  - **Buffer Zone:** Limited human activity allowed for research, monitoring, and education.
  - **Transition Area:** Permits ecologically sustainable human settlements and economic activities.

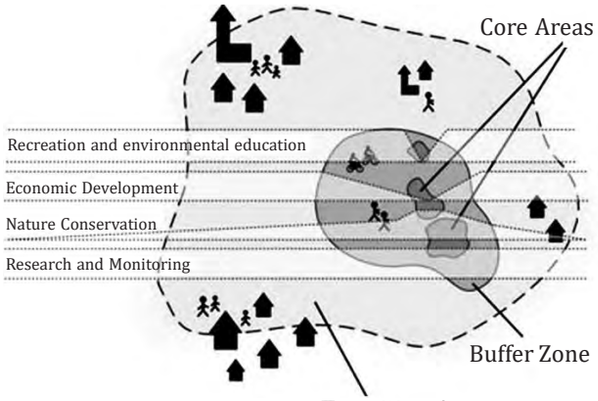


Fig. 10.27: Core, Buffer and Transition Zones

- **Protected Areas in Terms of Protection:** Protected forests < Reserved forests < Wildlife Sanctuaries < National Parks.
- The "**Miyawaki method**" is well known for the Creation of mini forests in urban areas National Parks.

Community and Conservation Reserves (WPA Amendment 2002)

Under the **Wildlife Protection Act (WPA), 1972**, as amended in **2002**, **Community Reserves** and **Conservation Reserves** were introduced to promote biodiversity conservation with community involvement.

- **Community Reserves**
  - **Purpose:** Protects ecosystems with active community participation.
  - **Management:** Local communities collaborate in conservation, balancing biodiversity protection with sustainable use of resources.
  - **Rights of Communities:** Communities can access forest resources sustainably, but activities that harm biodiversity are restricted.
- **Conservation Reserves**
  - **Purpose:** Protects wildlife habitats outside existing protected areas, often acting as buffer zones.
  - **Management:** Managed by government, with some community involvement.
  - **Rights of Communities:** Limited, focusing on sustainable resource use.

Sacred Groves in India

Sacred groves are forested areas preserved by local communities due to religious or spiritual significance, playing a key role in biodiversity conservation and cultural heritage. India is estimated to have around 100,000 to 150,000 sacred groves (IUCN).

Sacred Groves are protected under the Wildlife Protection Act, 1972, especially through Section 36I (declaration of community reserves).

Famous Examples:

- **Kerala: Kavu** groves dedicated to deities like **Bhagavati**.
- **Madhya Pradesh: Bhoramdeo Sacred Grove**, preserved due to religious practices.
- **Northeast India:**
  - **Meghalaya: Sohra Sacred Groves** (Cherrapunji region), rich in biodiversity.
  - **Nagaland: Mokokchung Sacred Groves**, integral to the Ao tribe's traditions.
  - **Manipur: Loktak Lake Sacred Groves**, important for both ecology and spirituality.

Ecologically Sensitive Zones (ESZs)

Purpose: ESZs, notified by the Ministry of Environment, act as buffers around national parks and wildlife sanctuaries to minimize forest depletion and human-animal conflict.

Key Features:

- **Regulations:** Mandated by the **National Wildlife Action Plan (2002–2016)** for areas within 10 km of protected zones. Additional ecologically important corridors may also be designated.
- **Supreme Court Directive (2022):** Minimum 1 km ESZ around protected areas.
- **Core and Buffer Model:** ESZs follow this model for conservation.

Legal Framework:

- Governed by the **Environment (Protection) Act, 1986**, allowing regulation of activities in sensitive zones.

Activities:

- **Prohibited:** Commercial mining, polluting industries, hydropower projects, aerial tourism.
- **Regulated:** Tree felling, agriculture, water use, hotels.
- **Permitted:** Local agriculture, organic farming, rainwater harvesting, renewable energy.

- The 'Biodiversity Heritage Sites' are unique ecosystems having rich biodiversity comprising of any one or more of the following components:
  - Richness of wild as well as domesticated species or intra-specific categories.
  - High endemism.
  - Presence of rare and threatened species, keystone species, species of evolutionary significance.
  - Wild ancestors of domestic/cultivated species or their varieties.
  - Under Section-37 of the Biological Diversity Act, 2002, the State Government, in consultation with local bodies, may notify areas of biodiversity importance as BHS.

Preservation of Western and Eastern Ghats

- **Western Ghats spans six states,** showcasing high species endemism and is recognized as a UNESCO World Heritage Site.
- Eastern Ghats face threats like deforestation, sand mining, and human encroachment.
- **The Madhav Gadgil Committee** recommended stringent measures for the conservation of the Western Ghats, but the **Kasturirangan Committee** diluted some proposals.
  - Recommendations of the Kasturirangan-led Panel: It notified **only 37% (against 64% by Gadgil commission**) of the area as ecologically sensitive.
- October 2018 notification by MoEF aimed to protect the Western Ghats by declaring ~57,000 sq km as ecologically sensitive areas.

EX SITU CONSERVATION

Ex situ conservation involves relocating threatened animals and plants from their natural habitats to protected environments for special care and management. Examples include:

- **Zoological Parks:** For animal conservation and breeding.
- **Botanical Gardens:** For preserving plant species.
- **Wildlife Safari Parks:** For conserving wildlife in semi-natural settings.
- **Seed Banks:** For storing seeds of plants for long-term preservation.

Advanced Techniques in Ex Situ Conservation

- **Cryopreservation**
  - Involves preserving gametes (e.g., sperm and eggs) of threatened species at very low temperatures.
  - Ensures the storage of viable and fertile gametes for extended periods.
- **In Vitro Fertilization (IVF)**
  - Eggs are fertilized in a laboratory setting to produce offspring for conservation purposes.
- **Tissue Culture**
  - Plants are propagated in controlled environments using tissue culture techniques to produce genetically identical plants.

INDIA'S INITIATIVES AND INSTITUTION TO PRESERVE BIODIVERSITY

Quarantine Centres to Check Invasive Species

- Plant quarantine centers at major entry points are **under the Central Board of Indirect Taxes**

and Customs in coordination with the DDQS (Directorate of Plant Protection and Quarantine Storage).

- DPPQS of the Ministry of Agriculture and Farmers' Welfare is responsible for the control of invasive pests/weeds.
- **Governed by the Destructive Insects and Pests Act, 1914,** these centers check imported agricultural products for phytosanitary certificates.
- **Fumigation with methyl bromide is done if needed,** and a phytosanitary certificate is issued.

National Biodiversity Authority (NBA)

- **Established:** 2003 under the **Biological Diversity Act, 2002**.
- **Headquarters:** Chennai, Tamil Nadu.
- **Purpose:** Regulate access to India's biological resources. Ensure fair and equitable sharing of benefits from resource utilization. Protect indigenous and traditional knowledge.
- **Key Roles:**
  - Prevent biopiracy and unauthorized use of genetic resources.
  - Approve IPR applications involving genetic/ biological resources.
  - Advise the Central and State Governments on biodiversity conservation.
  - Safeguards traditional crop varieties and genetic resources.
  - Supports sustainable agricultural practices and benefit-sharing with farmers.

Historic Citizen Movements

- **Sundarlal Bahuguna**, an environmentalist known as the **Defender of the Himalayas and Environmental Gandhi**, led the Chipko and Tehri dam movements.
- The Chipko Movement, starting in 1973, involved tree hugging to prevent deforestation and led to people-sensitive forest policies.
- The **Appiko Movement** (1983) in Karnataka and the **Anti-Tehri Dam Protest** were inspired by the success of the Chipko Movement.
- Women played a crucial role in the **Chipko Movement**, with **Gaura Devi** leading in Reni Village.
- Sundarlal Bahuguna's efforts resulted in a 15-year ban on cutting green trees after a meeting with Indira Gandhi in 1980.

GLOBAL INITIATIVES AND FRAMEWORKS FOR BIODIVERSITY CONSERVATION

Convention on Biological Diversity (CBD)

- **Legally binding multilateral treaty established in 1992** during the Earth Summit in Rio de Janeiro.
- Aim to achieve sustainable development through **3 main goals:**
  - The conservation of biological diversity.
  - Sustainable utilization of its components.
  - Fair sharing of benefits arising from genetic resources.
- 196 parties to the Convention- all UN member states, excluding the United States, have ratified.

Cartagena Protocol (on Biosafety)

- International agreement adopted in 2000, part of the CBD. (entered into force in 2003)
- **Focuses on the safe handling, transport, and use of living modified organisms resulting from modern biotechnology.**
- Aims to address technology development, transfer, benefit-sharing, and biosafety issues.
- India is a party.

Nagoya Protocol (on Access and Benefit-sharing)

- Adopted in 2010, it is a supplementary agreement to the CBD.
- Focuses on access to genetic resources and the fair and equitable sharing of benefits arising from their utilization.
- Entered into force in 2014, with currently 142 parties, including India.
- In India, the **Biodiversity Management Committees** are key to the realisation of the objectives of the Nagoya Protocol. The Biodiversity Management Committees have important functions in determining access and benefit sharing, including the power to levy collection fees on the access of biological resources within its jurisdiction.

Aichi Biodiversity Targets

- **Aichi Biodiversity Targets were adopted at COP 10 in Nagoya, Japan (2010) as a part of Strategic Plan for Biodiversity 2011-2020.**
- Includes goals to address underlying causes of biodiversity loss, reduce direct pressures, safeguard ecosystems, enhance benefits from biodiversity, and promote participatory management.
- **None of the 20 targets have been met** according to CBD's Global Biodiversity Outlook 5 report.

COP-15 of the UN CBD, 2022: Montreal, Canada

- Adopted the Kunming-Montreal Global Biodiversity Framework (post 2020 Global Biodiversity Framework).
- **Sets four global goals to be achieved by 2050**, including reducing extinction rates, sustainable biodiversity use, fair benefit-sharing, and closing the biodiversity finance gap.

- A new **Global Biodiversity Framework Fund** will be established **under the Global Environment Facility**. It targets at least USD 200 billion annually by 2030.
- **India's Demands at COP 15:**
  - Urgent need for a dedicated fund to assist developing countries.
  - Emphasis on **'Common but Differentiated Responsibilities and sRespective Capabilities'** for biodiversity conservation.

Post-2020 Global Biodiversity Framework: Kunming-Montreal Protocol

- **4 global goals by 2050:** Reducing the extinction rate and risk of all species tenfold (by 2050); sustainable biodiversity use; fair benefit-sharing; and adequate finance and technology to implement the **Kunming-Montreal Global Biodiversity Framework**, progressively closing the biodiversity finance gap of 700 billion $ annually.
- **23 targets by 2030,** covering threat reduction, sustainable use, implementation tools, and mainstreaming biodiversity.

COP-16 of the UN CBD, 2024: Cali, Colombia

- Establishment of a Permanent Body for Indigenous Peoples and Local Communities (IPLCs)
- A new subsidiary body was created to ensure the active participation of IPLCs in biodiversity-related decision-making processes.
- This initiative acknowledges the vital role of traditional knowledge in conservation efforts.
- **Launch of the 'Cali Fund' for Digital Sequence Information (DSI)**
  - An agreement was reached to implement a 0.1% fee on large biotechnology companies utilizing genetic resources.
  - The revenue will be directed into the newly established 'Cali Fund,' with 50% allocated to support Indigenous communities.
- **Advancements in Monitoring Frameworks**
  - Delegates agreed on frameworks to monitor progress toward the goals set by the Kunming-Montreal Global Biodiversity Framework.
  - These frameworks are designed to enhance transparency and accountability in conservation efforts.
- **Recognition of the Role of People of African Descent**
  - The conference acknowledged the significant contributions of people of African descent in biodiversity conservation.
  - This recognition aims to promote inclusive conservation strategies that leverage diverse cultural perspectives.
- **Unresolved Issues on Financial Resource Mobilization**
  - Despite progress in several areas, the conference concluded without a consensus on a comprehensive roadmap for funding biodiversity conservation.
  - This impasse highlights ongoing challenges in securing adequate financial commitments to meet global biodiversity targets.

International Treaty on Plant Genetic Resources for Food and Agriculture (PGRFA)

- Known as the **International Seed Treaty,** aligns with CBD.
- **Aims to guarantee food security** through the conservation, exchange, and sustainable use of plant genetic resources, ensuring fair and equitable benefit-sharing.

Global Partnership on Forest and Landscape Restoration (GPFLR)

- A global network to restore lost and degraded forests **(initiated by IUCN)**.
- **Aligns with the Bonn Challenge, aiming to restore 150 million hectares by 2020 and 350 million hectares by 2030.**

Bonn Challenge

- Launched in 2011(**Government of Germany and IUCN**), targets **restoring 350 million hectares of deforested and degrasssded land by 2030(under New York Declaration on Forests).**
- **India joined voluntarily**, pledging to restore 26 million hectares by 2030.

Forest Landscape Restoration (FLR)

- **Coined in 2000 by IUCN and WWF,** FLR aims to regain ecological integrity and enhance human well-being in deforested and degraded landscapes.
- Involves a planned process focusing on entire landscapes.

Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services) (IPBES)

- **IPBES, based in Bonn, Germany, comprises almost 150 member countries, including India.**
- Estimated 8 million species on Earth, with 1 million threatened with extinction, including 40% of amphibians, 33% of reef-forming corals, and over a third of marine mammals.
- **IPBES is often termed the "Intergovernmental Panel on Climate Change (IPCC) for biodiversity."**

XV World Forestry Congress and Seoul Declaration

- Held in Seoul with a theme of building a green, healthy, and resilient future with forests.
- Held every six years since 1926 under the auspices of FAO (entrusted the responsibility in 1954) and organised by the government of the host country.

- **Seoul Declaration** stresses a transition to a **circular bioeconomy** and achieving climate neutrality.

FEW INITIATIVES BY THE UN

United Nations Strategic Plan for Forests 2017–2030

- Adopted at the UN Forum on Forests in 2017 and ratified by the UN General Assembly.
- Features six Global Forest Goals with 26 associated targets to be achieved by 2030.
- **Includes a voluntary and universal target to increase global forest area by 3% by 2030,** equivalent to a 120 million-hectare increase.

Decade on Ecosystem Restoration (2021–2030)

- Proclaimed **by the United Nations General Assembly.**
- Aims to work towards ecosystem restoration from 2021 to 2030.

CLIMATE CHANGE

Long-term shifts in temperatures and weather patterns attributed to human activity altering the composition of the atmosphere.

Global Warming

It refers to the long-term rise in global temperatures, which is a part of climate change caused by the greenhouse effect. Rising temperatures due to global warming trigger a cascade of other effects, including rising sea levels, melting glaciers, loss of polar ice caps (cryosphere), ocean acidification etc.

Knowing Climate Change

- **Tree Rings as Climate Records:** The width and colour of these rings provide insights into past climate conditions, with wider rings indicating wetter periods and thinner rings indicating drier years.
- **Rock Layers:** Sedimentary rocks record changes in temperature, rainfall, and ocean currents through their composition and fossil content.
- **Pollen Records:** Pollen grains from different plant species are preserved in soils and lake sediments.
- **Ice Cores:** Deep ice cores drilled from polar regions trap bubbles of air and layers of snow from thousands of years ago
- Further **Coral Reefs, Cave speleothems, lake sediment** also help in knowing past climate change events.

CAUSES OF CLIMATE CHANGE

The primary mechanism behind rising global temperatures and resultant climate change is the greenhouse effect caused by greenhouse gas emissions.

Greenhouse Effect

- The **greenhouse effect** is the natural process by which certain gases in Earth's atmosphere, such as carbon dioxide (CO_2), methane (CH_4), and water vapor, trap heat from the Sun, allowing sunlight to enter the atmosphere but prevent some of the heat from escaping back into space, keeping the planet warm enough to support life.
- **Importance**: Natural Greenhouse effect sustains life by maintaining average global temperatures around 15°C. Without it, temperatures might plummet to -17°C, rendering life unsustainable. However, excessive greenhouse gas emissions from human activities intensify this effect, leading to global warming and climate change.

Main Causes of Climate Change

- **Greenhouse Gas Emissions**: Excessive release of carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O) from burning fossil fuels, deforestation, agriculture, and industrial processes. (RAS 2016/2013)
- **Deforestation**: Clearing forests reduces carbon sequestration, increasing atmospheric CO_2 levels.
- **Industrial Activities**: Factories emit greenhouse gases and pollutants, contributing to global warming.
- **Agriculture**: Livestock farming releases methane, and fertilizer use emits nitrous oxide.
- **Urbanization**: Increased energy use and waste generation amplify emissions.
- **Land Use Changes**: Converting natural habitats into agricultural or urban areas disrupts ecosystems and carbon cycles.
- **Aerosols**: Emitted by industries and vehicles, they affect atmospheric temperature and weather patterns.

IMPORTANT GREENHOUSE GASES

Greenhouse Gas	Key Features	Additional Information
Carbon Dioxide (CO_2)	❖ Transparent to incoming solar radiation but traps outgoing terrestrial radiation. ❖ Highest contributor to the greenhouse effect.	❖ **Total Earth carbon:** 1.85 billion gigatons. ❖ **Human Emissions:** 40–100 times more than volcanic emissions. ❖ Carbon Reservoirs ❖ India ranks second in the Asia–Pacific region in CO_2 emissions from fuel combustion, after China. ❖ Electricity and heat production is the largest contributor to India's CO_2 emissions.

		❖ **Carbon Reservoirs:** Below the Surface: 97.73% of total carbon. Above the Surface: 2.27% (Breakdown: Deep Ocean: 85.1%; Marine Sediments: 6.9%; Terrestrial Biosphere: 4.6%; Surface Ocean: 2%; Atmosphere: 1.4%).
Methane (CH_4)	❖ Second most significant greenhouse gas after CO_2, responsible for at least 30% of global warming. ❖ Odourless, colourless, and lighter than air; burns with a blue flame.	❖ The Global Methane Budget estimates that annual global methane emissions are around 580 Mt, with 60% from human activity and 40% from natural sources ❖ The largest sources of methane from human activities are: ➢ Agriculture, including livestock, stubble burning, and rice paddies; fossil fuels, including oil and natural gas systems, coal mining, and the production and transportation of coal, natural gas, and oil; decomposition of landfill waste; Wastewater treatment,etc ❖ Wetlands are the largest natural source of methane
Ozone (O_3)	❖ Found primarily in the stratosphere,where it absorbs harmful UV radiation. ❖ Ground-level ozone is a secondary pollutant formed from precursor gases reacting with sunlight and oxygen.	❖ Formed from Carbon Monoxide (CO), Nitrogen Dioxide (NO_2), and Volatile Organic Compounds (VOCs). ❖ Crop/biomass burning releases CO, O_3, Methane (CH_4), and Sulphur Dioxide (SO_2). ❖ Tropospheric ozone absorbs long wave terrestrial radiation, thus raising the earth's temperature.
Water Vapour	❖ Variable concentration (0.02%–4%) based on climate. ❖ Decreases with altitude, with 90% of moisture within 6 km of Earth's surface. ❖ Concentration diminishes from the equator to the poles.	❖ The insulating effect is weaker than CO_2. ❖ Contributes to atmospheric insulation by absorbing infrared radiation.
Nitrous Oxide (N_2O)	❖ NO and NO_2 act as global cooling gases, while N_2O is greenhouse gas. ❖ N_2O is a potent greenhouse gas that traps heat in the atmosphere more than carbon dioxide	❖ Emissions increased by 30% (1980–2016), with 43% attributed to human activities. ❖ Primarily released from agriculture,especially nitrogen-based fertilizers and burning of agriculture residues; industry; fuel combustion; etc.
Black Carbon (Soot)	❖ Strong absorber of sunlight, reduces Earth's albedo, and contributes significantly to warming after CO_2. ❖ Short-lived, remaining in the atmosphere for only days to weeks.	❖ Black carbon is the sooty black material emitted from gas and diesel engines, coal-fired power plants, and other sources that burn fossil fuel. ❖ It results from incomplete combustion of fossil fuels.
Carbon Monoxide (CO)	❖ Short-lived and indirect greenhouse gas. ❖ Oxidizes into CO_2, indirectly increasing methane and tropospheric ozone concentrations.	❖ Carbon monoxide forms whenever carbon-based fuels including coal, oil, natural gas and wood are burned. ❖ Carbon monoxide reacts with hydroxyl (OH) radicals in the atmosphere, reducing their abundance. As OH radicals help to reduce the lifetimes of strong greenhouse gases, like methane, carbon monoxide indirectly increases the global warming potential of these gases. ❖ Carbon monoxide in the atmosphere can also lead to the formation of the tropospheric greenhouse gas ozone

Fluorinated Gases

Although primarily responsible for ozone depletion, they are also potent greenhouse gases.

Compound	Characteristics
CFCs (Chlorofluorocarbons)	Used in refrigeration, solvents, aerosols, plastic foams, cleaning certain electronic components and industrial applications. Phased out due to ozone depletion. **Potent GHGs with higher greenhouse effect potential than CO_2.**
HFCs (Hydrofluorocarbons)	Used in refrigeration, aerosols, foam agents, fire retardants solvents, etc. as CFC replacements. **Potent GHGs** with long atmospheric lifetimes. Hydrofluorocarbons (HFCs) GWPs range from 140 to 11,700, lifetimes vary between 1 to 270 years.
PFCs (Perfluorocarbons)	❖ Composed of carbon and fluorine. Emitted during aluminium production, semiconductor manufacturing. ❖ **Perfluorocarbons (PFCs) GWPs between 6,500 to 9,200, lifetimes span from 800 to 50,000 years.**
SF_6(Sulphur Hexafluoride)	❖ Used in **magnesium processing,** semiconductor manufacturing, and as a **tracer gas**. ❖ Sulphur hexafluoride (SF_6) GWP of 23,900, lasts around 3,200 years in the atmosphere.

Short-Lived Climate Pollutants (SLCPs)

They are atmospheric pollutants with a relatively short lifespan but a significant impact on climate change and air quality. Key SLCPs include **methane (CH_4)**, **black carbon (soot)**, **tropospheric ozone (O_3)**, and **hydrofluorocarbons (HFCs)**.

Global Warming Potential & Lifetime of GHGs

Global Warming Potential (GWP) measures heat absorbed by a greenhouse gas (GHG) compared to the same mass of CO_2 over a specific time (usually 100 years).

Table 10.1: Global Warming Potential of Major Gases

Common Name (Chemical Formula)	Lifetime (Years)	GWP			GTP		
		20-year	100-year	500-year	20-year	100-year	500-year
Carbon dioxide (CO_2)	150†	1	1	1	1	1	1
Methane (CH_4)	12	72	25	76	57	12	4
Nitrous oxide (N_2O)	114	289	298	153	303	322	265
Sulphur hexafluoride (SF_6)	3200	16,300	22,800	32,600	17,500	23,400	28,000
Black carbon	0.020	1600	460	140	470	77	64

IMPORTANT TERMS

Carbon Footprint (RAS 2018)

❖ Measure of CO_2 produced through the impact from burning fossil fuels, is expressed in tons.

Carbon Bombs

❖ Covers coal, oil, or fossil gas projects with potential to emit over a Gigaton of CO_2. **Leave It In the Ground Initiative (LINGO)** identified 425 carbon bombs worldwide. According to LINGO, potential emissions exceed a 1.5°C carbon budget by a factor of two.

➢ Examples are **Carmichael Coal Project (Australia), Gevra Coal Mines (Chhattisgarh), Rajmahal Coal Mines (Jharkhand).**

Emission Intensity

Emission intensity is a measure of the amount of greenhouse gases (GHGs) released per unit of activity or output.

Activated Carbon

❖ Effective adsorbent for pollutant removal from effluents and contaminated sites

- It has large surface area with high capacity to adsorb heavy metals
- It can be produced from carbon-rich environmental wastes (biomass, agri-residues)

Climate Sensitivity

- It refers to the measure of how much the Earth's global average temperature will increase in response to a doubling of atmospheric carbon dioxide (CO_2) concentrations compared to pre-industrial levels. The value typically ranges between **1.5°C to 4.5°C**, depending on various factors and feedback mechanisms
- Pre-industrial CO_2 was about 260 ppm, with a doubling expected around 520 ppm in the next 50-100 years.

NOTE: The global average temperature has increased by about 1.8°F (1.0°C) over the last century due to human-induced climate change.**(RAS 2021)**

Feedback Mechanisms

These are processes that either amplify (positive feedback) or diminish (negative feedback) the effects of climate change.

- **Positive Feedback:**
  - **Ice-Albedo Effect:** Melting ice reduces surface reflectivity (albedo), leading to more heat absorption and further warming.
  - **Water Vapor Feedback:** Warmer temperatures increase water vapor (a greenhouse gas), amplifying the greenhouse effect.
  - **Permafrost Melting**: Releases methane and CO_2, enhancing global warming.
- **Negative Feedback**:
  - **Cloud Formation**: Increased evaporation can form more clouds, reflecting sunlight and cooling the surface.
  - **Plant Growth**: Higher CO_2 levels can boost plant growth, which absorbs more carbon.

IMPACT OF GLOBAL WARMING LED CLIMATE CHANGE

Climate change leads to multifaceted issues such as melting ice caps, rising sea levels, and extreme weather events. These changes disrupt ecosystems, threaten biodiversity, and pose severe risks to human health, food security, and economic stability.

Shrinking Cryosphere

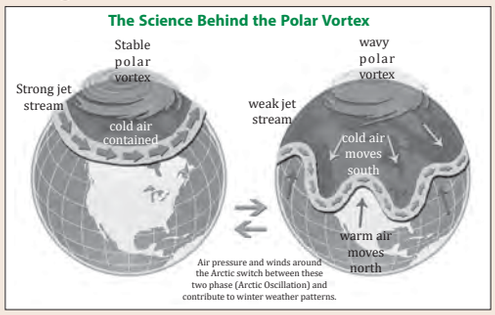
- Cryosphere comprises areas of snow or ice, including continental ice sheets, glaciers, permafrost, and frozen parts of oceans, rivers, and lakes.
- **Role of Cryosphere:** Reflects heat through high albedo, supplies freshwater to many parts of the world and is sensitive to climate shifts, acting as the Earth's "black box" for understanding past global climate changes.
- **Consequences of Shrinking Cryosphere**
  - **Vegetation Change:** Thawing of snow may increase arable land in high-latitude regions but reduce it along coastlines due to rising sea levels.
  - **Surge-Type Glaciers:** Surge-type glaciers can lead to catastrophic glacial lake outburst floods when they break due to global warming.
  - **New Sea Routes in the Arctic:** The Arctic is warming twice as fast as the global average, opening new sea routes, creating opportunities in shipping, energy, fisheries, and mineral resources.

Permafrost

- Permafrost is any ground that remains completely frozen—32°F (0°C) or colder—for at least two years straight.
- Permafrost is made of a combination of soil, rocks and sand that are held together by ice.

Arctic Oscillation

- The Arctic Oscillation (AO) is a phenomenon that describes how surface air pressure patterns relate to each other in the mid- to high-latitudes. This relationship influences the jet stream, which is a band of strong winds in the upper atmosphere that generally separates warm and cold air. Consequently, these strong winds influence weather in the midlatitudes, including the Great Lakes.


The Science Behind the Polar Vortex
Stable polar vortex
Strong jet stream
cold air contained
wavy polar vortex
weak jet stream
cold air moves south
warm air moves north
Air pressure and winds around the Arctic switch between these two phase (Arctic Oscillation) and contribute to winter weather patterns.

Arctic Oscillation

- The AO has two phases – positive and negative. It is typically measured via the AO index, which numerically describes the strength of the AO. During the positive phase of the AO, the jet stream is typically faster and located farther north, keeping cold polar air confined to the Arctic, and resulting in warmer, drier winter weather.
- During the negative phase, the jet stream is weaker and wavier, leading to colder air being able to extend southward into the Great Lakes region. The AO is naturally quite variable, and can fluctuate daily, monthly, seasonally, or annually. It is difficult to predict the behavior of the AO beyond a few days.
- The Arctic is warming faster than other parts of the globe. In recent decades, the Arctic has warmed nearly twice as much as the rest of the world.
- **Reasons:**
  - The loss of sea ice is one of the most cited reasons. When bright and reflective ice melts, it gives way to a darker ocean; this amplifies the warming trend because the ocean surface absorbs more heat from the Sun than the surface of snow and ice. In more technical terms, losing sea ice reduces Earth's albedo: The lower the albedo, the more a surface absorbs heat from sunlight rather than reflecting it back to space.
- **Consequences: Melting polar ice and its resultant impact on climate patterns and extreme events.**

Sea Level Rise (SLR)

- Sea level rise refers to the increase in the average height of the world's oceans due to global warming. It occurs primarily due to two factors: thermal expansion and melting of ice.
- The IPCC Special Report on the Ocean and Cryosphere in a Changing Climate (SROCC) finds that global mean sea levels will most likely rise between 0.95 feet (0.29m) and 3.61 feet (1.1m) by the end of this century.
- The IPCC estimates that the rate of sea level rise is 3-6 times faster than over the last 100 years

More Severe Tropical Cyclones

- **Increasing Sea Surface Temperatures (SST)**
  - The South Indian Ocean is experiencing higher temperatures (30-32°C) compared to the previous norm of 26.5°C, contributing to more intense cyclones.
- **Global Forcing Mechanisms**
  - Regions farther from the equator are experiencing higher temperatures (24-26°C), expanding the potential range for cyclone formation.

Deterioration of Carbon Sinks

- **High Latitude Forests:** The **taiga and tundra regions store more carbon than tropical rainforests.** Global warming is causing the permafrost in these areas to melt, releasing stored carbon as carbon dioxide and methane.

Carbon Dioxide Fertilization

Stimulation of plant growth resulting from increased levels of atmospheric carbon dioxide. Higher levels of CO_2 can enhance this process, leading to increased plant growth in some cases.

Ocean Deoxygenation

- Refers to the expansion of oxygen minimum zones (OMZs) in the world's oceans due to human-induced carbon dioxide emissions.
- **OMZs:** These zones are characterized by low oxygen concentrations **caused by** warmer oceans, which reduce oxygen solubility in water and contribute to temperature-driven stratification.
- **Effects of Ocean Deoxygenation: Element Cycling (**Reduction in the cycling of essential elements such as carbon, nitrogen, and phosphorus etc), biodiversity loss, changes in fishes habitats and livelihoods in coastal areas.

Ocean Acidification

- Ocean acidification refers to the ongoing decrease in the pH of the Earth's oceans caused by the absorption of excess atmospheric carbon dioxide (CO_2). Since the late 1980s, 95 percent of open ocean surface water has become more acidic. Oceans absorb about 30 per cent of carbon dioxide (CO_2) we produce, reducing the pH of seawater.
- When CO_2 dissolves in seawater, **it reacts to form carbonic acid,** which lowers the pH.
- **Today, the ocean's average pH is 8.1. This means that the ocean today is about 30 per cent more acidic than in pre-industrial times. By 2100, the pH of the ocean could decrease to about 7.8, making the ocean 150 percent more acidic** and affecting half of all marine life, according to the **Intergovernmental Panel on Climate Change (IPCC) Sixth Assessment Report.**

Coral Bleaching or Coral Reef Bleaching

- **Coral bleaching** occurs when corals expel the symbiotic algae (**zooxanthellae**) living in their tissues, causing them to lose their color and appear white and is primarily caused by environmental stress, particularly rising sea temperatures due to global warming.

Causes for Coral Bleaching

- **Temperature Changes, Ocean Acidification, Increases Inorganic Nutrients** are the major causes.
- **Subaerial Exposure:** Exposure to the atmosphere during low tides or sea level drops induces bleaching.
- **Xenobiotics:** Exposure to high concentrations of contaminants like copper, herbicides, and oil can cause bleaching.
- **Epizootics:** Coral diseases, although not directly related to bleaching, may cause adverse effects on coral health.

Biorock Technology for Coral Restoration

- Biorock technology, involving mineral accretion or electro-accumulation on steel structures, is used for coral restoration.
- Passing electrical current through electrodes in the water results in the formation of biorock, aiding coral growth.

Other Technologies for Coral Restoration

- **Coral Gardening**:
  - Fragments of coral are grown in underwater nurseries or artificial structures until they are large enough to be transplanted back to reefs.
- **Microfragmentation**:
  - Breaks coral into small pieces to speed up growth rates. Useful for slow-growing coral species like brain corals.
- **3D-Printed Reefs**:
  - Artificial reefs made from eco-friendly materials (e.g., limestone, sandstone) are 3D-printed to mimic natural reef structures.
- **Cryopreservation**:
  - Freezing coral gametes, larvae, or polyps at ultra-low temperatures for future use in restoration projects.
- **Larval Propagation**:
  - Captures coral spawn during natural spawning events, raises larvae in controlled environments, and releases them onto damaged reefs.
- **Algae Manipulation:**
  - Coral relies on symbiotic algae (zooxanthellae) for energy. Introducing stress-tolerant algae strains can improve coral survival under adverse conditions.
- **Coral Adhesive Technology:** Development of underwater glues and bio-adhesives to securely attach coral fragments to substrates.
- **Sunshields and Cooling Devices**: Technologies to reduce ocean surface temperature or block excess sunlight to prevent coral bleaching.

TACKLING CLIMATE CHANGE

Strategy to tackle climate change can be divided into mitigation and adaptation strategies.

Comparison between Climate Change Mitigation and Adaptation

Aspect	Mitigation	Adaptation
Definition	Actions aimed at reducing or preventing greenhouse gas emissions to slow down climate change.	Actions taken to adjust to the impacts of climate change to reduce harm and increase resilience.
Examples	Transition to renewable energy sources. Energy efficiency improvements. Afforestation and reforestation.	Building resilient infrastructure. Developing drought-resistant crops. Early warning systems for disasters.

Climate Change Mitigation

Clean Coal Technology

It refers to a collection of advanced technologies and processes designed to enhance the efficiency of coal usage while reducing its environmental impact.

- **Coal Preparation (Coal Washing):** Removes unwanted minerals by mixing crushed coal with a liquid, allowing impurities to separate and settle.
  - Unlike majority of American coal, Indian coal has low-sulphur coals. Studies show that the sulphur content in Indian coal is hardly 0.7%, which is not uniformly distributed in the coal but concentrated in the pyritic bands which are visible to the naked eye. The best solution to get rid of sulphur from Indian coal is to wash it.
- **Electrostatic Precipitators, Coal Gasification,Wet Scrubbers.**
- **Low-NOx Burners:** Reduce nitrogen oxides creation by restricting oxygen and manipulating the combustion process.
- **Replace India's Coal**
  - India's coal is poor-quality Gondwana coal with less carbon, high ash, and high moisture content.
  - The suggestion is to replace sub-critical coal power plants with super-critical and ultra-super-critical ones for increased efficiency.

Carbon Dioxide Removal (CDR) Techniques

CDR techniques aim to remove CO_2 from the atmosphere and store it securely to mitigate climate change. These can be categorized into nature-based and technology-based approaches.

Category	Technique	Description
Nature-Based	Afforestation/ Reforestation	Planting trees to absorb CO_2 through photosynthesis and store it in biomass.
	Soil Carbon Sequestration	Enhancing soil's ability to store carbon through sustainable agriculture and organic matter addition.
	Blue Carbon Ecosystems	Protecting/restoring coastal ecosystems (e.g., mangroves, seagrasses) to capture CO_2 in vegetation and sediments.
	Biochar	Burning biomass in low-oxygen environments to produce a carbon-rich material that can enrich soil.
Technology Based	Direct Air Capture (DAC)	Using chemical processes to capture CO_2 directly from the air, which is then stored or utilized. **Captured CO_2** from Direct Air Capture can be used in plastic production and food processing (e.g., carbonated beverages) and can also be combined with green hydrogen to produce synthetic low-carbon aviation fuels (e-fuels).
	Carbon Capture and Storage (CCS)	Capturing CO_2 emissions from industrial processes or power plants and storing it underground. Storage options include geological (injecting CO_2 into the earth) and oceanic methods.
	Bioenergy with CCS (BECCS)	Burning biomass for energy, capturing the emitted CO_2, and storing it underground.
	Ocean Fertilization	Adding nutrients (e.g., iron) to oceans to stimulate phytoplankton growth, which absorbs CO_2.
Hybrid Approaches	Enhanced Weathering	Spreading crushed silicate rocks on land or ocean surfaces to accelerate natural CO_2 absorption.
	Marine Algae Cultivation	Growing algae in oceans to absorb CO_2 and potentially store carbon in deep sea ecosystems.
Others	Mineral Carbonation	Reacting CO_2 with minerals to form stable carbonates for long-term storage.
	Carbon capture and Utilization	Converting captured CO_2 into products like fuels, chemicals, or building materials.

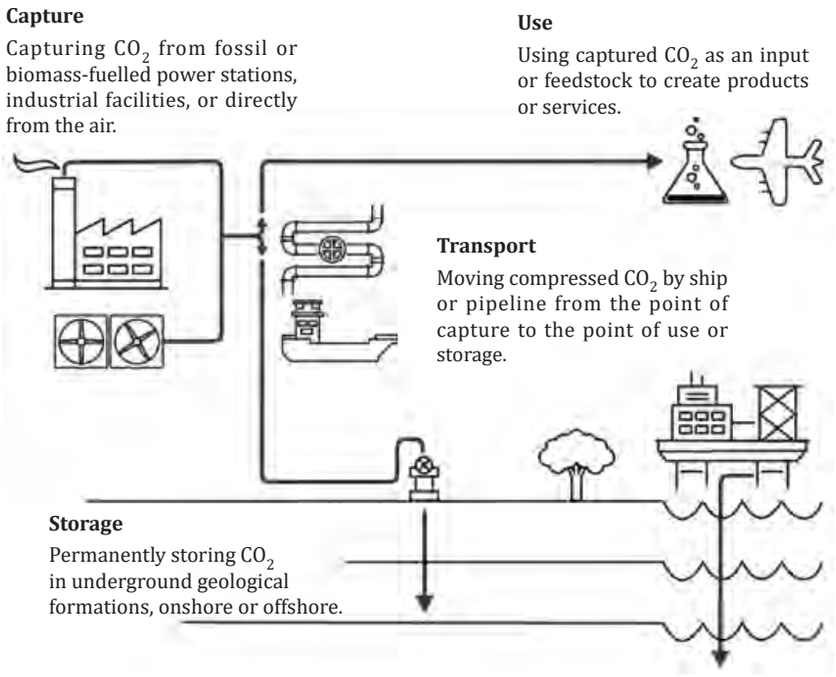

Capture
Capturing CO_2 from fossil or biomass-fuelled power stations, industrial facilities, or directly from the air.
Use
Using captured CO_2 as an input or feedstock to create products or services.
Transport
Moving compressed CO_2 by ship or pipeline from the point of capture to the point of use or storage.
Storage
Permanently storing CO_2 in underground geological formations, onshore or offshore.

Fig. 10.28: Carbon Dioxide Removal Techniques

Geoengineering

- Deliberate large-scale interventions in Earth's natural systems to counteract climate change.
- Solar Radiation Management (SRM) techniques aim to reflect sunlight away, while GHG Removal (GGR) involves directly removing CO_2 or other GHGs.

Transition Away from Coal

- IPCC recommends a significant reduction in coal-powered electricity to limit global warming.
- Some countries, like the UK, France, Italy, and Germany, have committed to phasing out coal-fired electricity.
- **Barriers to Phasing Out Coal Power:** Economic and political barriers, including stranded assets, livelihood impacts, electricity prices, and irresponsible financing.

Climate-Smart Cities

- Climate-Smart Cities are urban areas designed to adapt to climate change while reducing greenhouse gas emissions and promoting sustainable, resilient growth
- Measures include cool pavements, green roofs, decentralization, and improving ventilation.
- **Cooling Singapore Case Study:** Initiative to reduce the urban heat island effect in Singapore, including green roofs, vertical greenery, and district cooling.
- **Climate-Smart Cities Assessment Framework (CSCAF):** A framework to guide cities in combating climate change, covering energy, urban planning, mobility, water, and waste management.
- **Green Rating for Integrated Habitat Assessment (GRIHA):** National rating tool assessing the environmental performance of buildings.
- **Transition to Green Economy:** Priorities include decarbonizing the economy, ensuring justice and equity, and conserving the biosphere.
- **Green Contracts:** Commercial contracts mandating GHG emission reductions during the delivery of goods/services.

INTERNATIONAL ENVIRONMENTAL CONVENTIONS, ORGANIZATIONS AND LAWS

United Nations Conference on the Human Environment (1972)

- Held in 1972 at **Stockholm, Sweden,** it played a role in the emergence of international environmental law.
- The conference led to the adoption of the Stockholm Declaration and the Action Plan for the Human Environment.
- The Stockholm Declaration is also known as The Declaration on the Human Environment.

UN Environment Programme (UNEP)

- **Role:** UNEP is a UN agency that coordinates environmental activities, assists developing countries in implementing environmentally sound policies, and has overall responsibility for environmental issues within the UN system formed as an outcome of the Stockholm conference.
- **Agencies Established/Implemented by UNEP**
  - Intergovernmental Panel on Climate Change **(IPCC) in 1988** (with the World Meteorological Organization).
  - **Implementing** agencies for the **Global Environment Facility (GEF)** and the Multilateral Fund for the Montreal Protocol.
  - **Member of the United Nations Sustainable Development Group (UNSDG)** to help achieve the 17 Sustainable Development Goals (SDGs).
  - Hosts the **secretariats** of various environmental agreements/research bodies, including **CBD, CMS, and CITES.**
  - Involved in successful agreements like the Montreal Protocol (1987) and the Minamata Convention (2012).
  - **Faith for Earth Initiative (FEI):** Launched: In **2017** by UNEP, to strategically engage with faith-based organizations to collectively achieve the SDGs, creating a global "Coalition for Creation" for policy dialogue on environmental issues.
  - Major Reports: Emissions Gap Report, Global Environment Outlook (GEO).

UNCED/Earth Summit, Rio De Janeiro(1992)

- The conference played a crucial role in raising public awareness about the integration of environment and development.
- **Landmark Agreements:** Climate Change Convention (UNFCCC): Initiated at the Earth Summit, this led to subsequent agreements like the Kyoto Protocol and the Paris Agreement.
- **Legally Binding Agreements**
  - Convention on Biological Diversity (CBD)
  - United Nations Convention to Combat Desertification (UNCCD)
  - United Nations Framework Convention on Climate Change (UNFCCC)
- **Other initiatives**
  - **Agenda 21:** Non-binding action plan for global sustainable development.
  - **Forest Principles:** Non-legally binding document on the Conservation and Sustainable Development of all types of forests.

World Summit on Sustainable Development (Rio+10, 2002)

- Held in **Johannesburg, South Africa.**

- Affirmed the UN commitment to Agenda 21 alongside the Millennium Development Goals (MDGs).

Rio+20 (2012) or Earth Summit 2012

- A 20-year follow-up to the Earth Summit 1992 and a 10-year follow-up to the Earth Summit 2002.
- Sustainable Development Goals **(SDGs) were born at Rio+20, later included in the Agenda 2030.**

Partnership for Action on Green Economy (PAGE)

- Launched in 2013 as a response to the Rio+20 Declaration, "The Future We Want."
- Aims to assist countries in achieving SDG 8, promoting sustained, inclusive, and sustainable economic growth with full and productive employment.

High-level Political Forum on Sustainable Development (HLPF)

- **Role:** A forum under the UN Economic and Social Council (**ECOSOC**) responsible for overseeing the outcomes of the 1992 Earth Summit.
- **Meetings:** Convenes every four years under the General Assembly and in other years under ECOSOC.
- **Responsibilities:** Oversees the implementation progress of various outcomes, including Agenda 21, Johannesburg Declaration (Rio+10), Rio+20, Barbados Programme of Action (Sustainable Development of SIDS), and LDC-IV (4th United Nations Conference on the Least Developed Countries).

TIMELINE OF IMPORTANT EVENTS

Year	Event	Key Highlights
1979	**First World Climate Conference (WCC)**	First global discussion on climate change.
1988	**Establishment of IPCC**	The Intergovernmental Panel on Climate Change (IPCC) was formed to assess climate science.
1990	**IPCC and WCC call for climate treaty**	The IPCC and Second WCC urged negotiations for a global climate treaty; the UN General Assembly initiated these discussions.
1992	**UNFCCC Text Adoption**	The text of the United Nations Framework Convention on Climate Change (UNFCCC) was adopted in New York.
1994	**UNFCCC Enters Into Force**	The treaty became legally binding for signatories.
1995	**COP 1 (Berlin, Germany)**	First Conference of the Parties (COP) under the UNFCCC.
1996	**UNFCCC Secretariat Relocates**	Moved from Geneva to Bonn, Germany, establishing Bonn as an international sustainability hub.
1997	**COP 3 (Kyoto, Japan) (RAS 2013)**	Adoption of the Kyoto Protocol, legally binding developed countries to emission reduction targets.
1978	**Buenos Aires Plan of Action**	Defined strategies for implementing the Kyoto Protocol.
2001	**COP 6-2 (Bonn, Germany)**	Governments achieved a major breakthrough by agreeing on operational rules for the Kyoto Protocol.
2001	**COP 7 (Marrakesh, Morocco)**	Adoption of the Marrakesh Accords, finalizing rules for mechanisms like International Emissions Trading, Clean Development Mechanism (CDM), and Joint Implementation (JI).
2002	**COP 8 (New Delhi, India)**	The Delhi Declaration emphasized development needs of the poorest countries and technology transfer for climate change mitigation.
2005	**Kyoto Protocol Enters Into Force**	Became binding with Russian Federation ratification.
2005	**COP 11/CMP 1 (Montreal, Canada)**	First Meeting of the Parties (MOP) to the Kyoto Protocol.
2006	**Clean Development Mechanism (CDM) Launch**	Opened for emissions reduction projects to generate Certified Emission Reduction (CER) units for trading.
2007	**COP 13 (Bali, Indonesia)**	Adoption of the Bali Road Map, outlining post-2012 climate action plans focused on mitigation, adaptation, technology, and financing.

2008	**COP 14 (Poznan, Poland)**	Launch of the Adaptation Fund under the Kyoto Protocol and the Poznan Strategic Programme on Technology Transfer.
2009	**COP 15 (Copenhagen, Denmark)**	Drafting of the Copenhagen Accord, with developed countries pledging USD 30 billion in fast-start finance (2010–2012).
2010	**COP 16 (Cancun, Mexico)**	Adoption of the Cancun Agreements, establishing the Green Climate Fund, Technology Mechanism, and Cancun daptation Framework.
2011	**COP 17 (Durban, South Africa)**	Governments agreed on a new climate agreement beyond 2020, leading to the Paris Agreement.
2012	**COP 18/CMP 8 (Doha, Qatar)**	Adoption of the Doha Amendment, launching the second Kyoto Protocol commitment period (2013–2020).
2013	**COP 19/CMP 9 (Warsaw, Poland)**	Establishment of the Warsaw Framework for REDD+ and the Warsaw International Mechanism for Loss and Damage.
2015	**COP 21 (Paris, France)**	Discussed below.
2016	**COP 22 (Marrakech, Morocco)**	Advanced the Paris Agreement rulebook and launched the Marrakech Partnership for Climate Action.
2017	**COP 23 (Bonn, Germany)**	Negotiated details of the Paris Agreement's operationalization. Hosted by Fiji, marking the first COP led by a small-island developing state.
2018	**COP 24 (Katowice, Poland)**	Finalized the Paris Agreement rulebook, covering NDCs and climate financing.
2019	**COP 25 (Madrid, Spain)**	Discussions yielded no concrete plans for addressing climate urgency.
2021	**COP 26 (Glasgow, UK)**	Discussed below
2022	**COP 27 (Sharm El Sheikh, Egypt)**	Discussed below
2023	**COP 28 (Dubai, United Arab Emirates (UAE)**	Discussed below
2024	**COP 29 (Baku, Azerbaijan)**	Discussed below

UNITED NATIONS FRAMEWORK CONVENTION ON CLIMATE CHANGE (UNFCCC)

- **Establishment**
  - UNFCCC is an international environmental treaty established in 1992 at the Rio Earth Summit (UNCED).
  - Negotiated in New York City, signed in 1992, and as of February 2023, it has 198 parties.
- **Role and Objective**
  - The primary role of UNFCCC is to provide a framework for negotiating specific international treaties, known as "protocols."
  - UNFCCC itself sets no binding limits but aims to stabilize greenhouse gas (GHG) concentrations in the atmosphere at a level preventing dangerous consequences.
- **Legal Status**
  - Considered legally non-binding, UNFCCC provides the foundation for legally binding protocols negotiated under its auspices.
- **Conferences of the Parties (COP)**
  - COP is the decision-making body of UNFCCC, representing all States that are Parties to the Convention. Annual meetings to review implementation and promote effective action.
- Parties to UNFCCC have been divided into 3 groups based on their commitments.

Group	Description	Countries Included	Commitment
Annex I Countries	Developed nations and economies in transition (EIT) with binding emission reduction targets.	Most European countries, Canada, Japan, Russia	Binding greenhouse gas emission reduction targets.

Annex II Countries	Annex I countries that are not EITs, required to provide financial resources to developing countries.	Developed Annex I countries (e.g., USA, UK, Germany)	Must provide financial resources for emission reduction and adaptation.
Non-Annex I Countries	Developing countries are not required to limit emissions under the Protocol.	China, India, countries in Africa and South America	No binding emission reduction commitments.

Kyoto Protocol (COP 3, 1997)

Aspect	Details
Kyoto Protocol Overview	Adopted on 11 December 1997, the Kyoto Protocol aimed to reduce carbon dioxide (CO_2) and greenhouse gas (GHG) emissions to mitigate climate change. Entered into force on 16 February 2005 with 192 signatories (as of 2022).
Target Gases	**Covered six GHGs:** CO_2, Methane (CH_4), Nitrous Oxide (N_2O), Hydrofluorocarbons (HFCs), Perfluorocarbons (PFCs), and Sulfur Hexafluoride (SF6).
Commitments	Focused on industrialized nations (Annex I countries), requiring them to cut emissions under the principle of "common but differentiated responsibilities".
First Commitment Period	**Annex B Targets:** Reduce emissions by an average of 5% below 1990 levels during 2008–2012.
Market Mechanisms	Introduced flexible mechanisms for meeting emission targets: ❖ **International Emissions Trading:** Sell unused emission allowances to other countries. ❖ **Clean Development Mechanism (CDM):** Invest in emission-reducing projects in developing countries for credit. ❖ **Joint Implementation (JI):** Collaborate on emission reduction projects between Annex I countries.
Monitoring and Compliance	Established systems for monitoring, reviewing, verifying emissions, and ensuring compliance. Developed nations' emissions were strictly tracked, while developing countries participated voluntarily.
Doha Amendment (2012)	❖ Adopted on 8 December 2012, introduced a second commitment period (2013–2020) with new targets: ❖ Reduce GHG emissions by 18% below 1990 levels. ❖ Updated GHG list and amended articles addressing the second commitment period.
Developing Nations	❖ Exempted from binding targets but could earn and trade carbon credits through emission-lowering projects (e.g., India, China). ❖ **Carbon Credit:** ❖ The carbon credit system was ratified in conjunction with the Kyoto Protocol. ❖ Carbon credits are awarded to countries or groups that have reduced greenhouse gases below their emission quota. ❖ The goal of the carbon credit system is to limit the increase of carbon dioxide emission.

Flexible Market Mechanisms under Kyoto Protocol

Mechanism	Description
Joint Implementation	When an industrialized country invests in an emission reduction project in another industrialized country, the amount reduced counts toward the investor's emission total.
Clean Development Mechanism	When an industrialized country invests in an emission reduction project in a developing country, the amount reduced counts toward the investor's emission reduction total.
International Emission Trading	Industrialized countries may buy and sell emission credits.

Paris Agreement (COP 21)

❖ The Paris Agreement is a legally binding international treaty on climate change. It was adopted by 196 Parties at the UN Climate Change Conference (COP21) in Paris, France, on 12 December 2015. It entered into force on 4 November 2016.

- Aims to limit global warming to "well below 2°C" and pursue efforts for 1.5°C.
- Developed countries committed to mobilize **$100 billion** a year in climate finance by 2020.
- Countries set **voluntary GHG reduction targets (NDCs)** and update them every five years with more ambitious goals.
- To limit global warming to 1.5°C, greenhouse gas emissions must peak before 2025 at the latest and decline 43% by 2030.
- **Article 6 – Cooperative Mechanisms :**
  - Provides a framework for international cooperation to achieve NDCs.
  - Enables carbon markets through Internationally Transferred Mitigation Outcomes (ITMOs).
  - Promotes non-market approaches such as policy coordination, technology transfer, finance, and capacity building.
  - Aims to enhance cost-effective mitigation and sustainable development.

India's NDC (Nationally Determined Contributions)

Target (for 2030)	Existing: First NDC (2015)	New: Updated NDC (2022)	Progress
Emission intensity reduction	33-35% from 2005 levels	45% from 2005 levels	33% reduction in emission intensity by 2019 from 2005 levels.
Share of non-fossil fuels in installed electricity capacity	40%	50%	45.4% achieved by the end of June 2024.
Carbon sink	Creation of 2.5 to 3 billion tonnes of additional sink through afforestation	Same as earlier	Carbon sink of 1.97 billion tonnes of CO2 equivalent has been created between 2005-2019

Kyoto Protocol vs Paris Agreement

Aspect	Kyoto Protocol	Paris Agreement
Year Established	Created in 1997 and ratified in 2005. Had two periods from 1997-2020.	Signed in November of 2016. New commitments are due every 5 years.
Emission Goals	Original commitment to decrease overall emissions by 5% from 1990 levels.	Overall goal to limit global temperatures to 2 degrees Celsius above pre-industrial levels.
Scope of Responsibility	Only required developed nations to reduce emissions.	Asked all nations to reduce emissions.
Climate Finance	Provides for flexible market mechanisms like CDM, Carbon trading and Joint Implementation.	Article 6 of the Paris Agreement provides for countries to co-operate through market and non market mechanisms such as SDM (Sustainable Development Mechanisms)

COP 26 (Glasgow) Major Outcomes

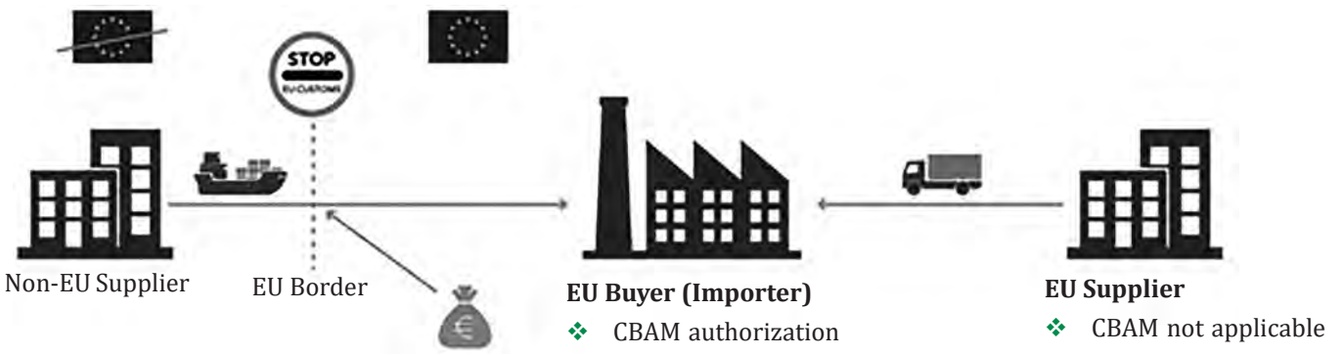
- **Glasgow Climate Pact:** Affirms the Paris Agreement's temperature goals, urging countries to strengthen 2030 climate action plans by 2022. Calls for coal phase-down, subsidy elimination, and $100 billion annual funding till 2025.
- **Carbon Markets:** Allows unused carbon credits for meeting countries' first NDC targets until 2025.
- **Paris Rulebook:** Finalizes rules for Paris Agreement implementation, enabling emissions reduction target pledges and progress reporting.
- **Article 6:** Establishes conditions for bilateral markets and a central global market (SDM) to avoid double counting of emissions reductions.
- **Global Methane Pledge:** Over 100 countries commit to 30% methane emission reduction by 2030, India not a party to it.
- **Enhanced Climate Actions:** Nations pledge zero-emission cars, revised net-zero targets (e.g., Brazil, China), and a cooperative agenda (Glasgow Breakthrough Agenda).
- **Glasgow Finance Alliance for Net Zero (GFANZ):** Over 160 firms commit to net-zero emissions by 2050, aligning with UN Race to Zero criteria.
- **India's Commitments (Panchamrit):** 50% renewable energy, 1 billion tonne emission reduction by 2030, <45% emissions intensity, 500 GW renewables by 2030, net-zero by 2070. Calls for $1 trillion climate financing.
- **"Phase Down of Coal":** India advocates for "phase down" rather than "phase out" in the pact, aiming to boost new technology viability.
- **Leaders' Declaration on Forests:** Over 100 countries commit to halting deforestation by 2030; India abstains due to concerns about interlinking trade and climate issues.

- India, along with the UK, launched the **Green Grids Initiative-One Sun One World One Grid** (GGI-OSOWOG), aimed at promoting cross-border energy grids to enable global solar energy deployment.
- **Mission LiFE (Lifestyle for Environment):** PM Modi launches a global initiative promoting sustainable living, circular economy, and individual/environmental harmony.

COP27 Major Outcomes

- **Venue and Participants**
  - The 27th UNFCCC COP took place in November 2022 in Sharm El-Sheikh, Egypt.
  - It included the 4th meeting of the parties to the 2015 Paris Agreement (CMA4) and the 17th meeting of the parties to the Kyoto Protocol (CMP17).
- **Global Shield Against Climate Risks Initiative**
  - Launched at COP27, this initiative involves collaboration between the V20 Group (comprising 58 climate-vulnerable countries) and G7 countries.
  - Aims to provide pre-arranged financial support for swift deployment during climate disasters.
  - Initial beneficiaries include Pakistan, Bangladesh, Costa Rica, Fiji, Senegal, Philippines, and Ghana.
- **UNODC Paper on Illegal Wildlife Trade (IWT)**
  - Highlighting the overlooked impact of IWT on ecosystem services related to climate change.
  - Trees like Dalbergia (e.g., Indian Rosewood), essential for carbon sequestration, are globally trafficked.
  - Endangered species like African Forest Elephants, white rhinos, and pangolins, recognized as Ecosystem Engineers, are threatened by IWT.
- **Long-Term Low-Emission Development Strategy (LT-LEDS)**
  - India submitted its LT-LEDS during COP27, aligning with the 2015 Paris Agreement's requirements.
  - Focuses on rational resource utilization, low-carbon strategies, and building climate resilience.
  - Strategies include increased use of biofuels, three-fold nuclear capacity increase by 2032, and green hydrogen adoption for low-carbon development.
- **Loss and Damage Fund**
  - A decision to establish and operationalize the Loss and Damage fund was made at COP27.
  - Aims to assist vulnerable poor and developing countries impacted by climate change with reparations.
- **Methane Alert and Response System (MARS)**
  - It is a satellite-based monitoring system to track methane emissions globally.
  - Part of UNEP's International Methane Emissions Observatory (IMEO), it alerts governments and corporations.
  - Supports the implementation of the Global Methane Pledge initiated at COP26.
- **Mangrove Alliance for Climate**
  - It was launched at COP27 by UAE and Indonesia to promote the conservation, restoration, and sustainable management of mangrove ecosystems in the fight against climate change. Mangroves play a critical role in mitigating climate change by sequestering large amounts of carbon, protecting coastal areas from storm surges, and supporting biodiversity. It is voluntary in nature with members being the United Arab Emirates (UAE),Indonesia, India, Australia, Japan, Spain, Sri Lanka.
- **African Carbon Market Initiative (ACMI):**
  - It was launched to support the growth of carbon credit production and create jobs in Africa.
- **New Zealand's Agricultural Emissions Tax**

Cross Border Adjustment Mechanism (CBAM) Explained



* Including goods originating from Iceland, Liechtenstein, Norway, and Switzerland

- **Carbon Border Tax**
  - The EU proposes a **carbon border tax** on imports based on their carbon emissions, starting from 2026.
  - The **BASIC group (India, China, Brazil, and South Africa) opposes the tax**, citing concerns about the principle of Common But Differentiated Responsibility (CBDR) from the Paris Agreement.

COP 28 at Dubai (2023) Major Outcomes

Global Stocktake (GST)

- Periodic review mechanism under the Paris Agreement (2015).
- This first GST cycle synthesized data from countries, scientific reports, and stakeholders to highlight gaps in emissions reduction, adaptation efforts, and climate finance.
- Proposes **eight steps** to limit global temperature rise to **1.5°C**.
- **Calls for:**
  - **Tripling global renewable energy capacity** by 2030.
  - **Doubling energy efficiency improvements** annually by 2030.
  - Substantial reduction in **non-CO2 emissions**, including **methane**, by 2030.

Transition from Fossil Fuels

- Advocates a **just, orderly, and equitable energy transition**.
- Targets **net-zero emissions by 2050**, with accelerated action in the current decade.

Global Goal on Adaptation (GGA)

- Focuses on enhancing **adaptive capacity** and minimizing **vulnerability** for sustainable development.
- Calls for:
  - Doubling **adaptation finance**.
  - Setting 2030 targets for **water security**, **ecosystem restoration**, and **health**.

Loss and Damage Fund

- Operationalized to compensate nations impacted by climate change.
- Priority funding for **Least Developed Countries (LDCs)** and **Small Island Developing States (SIDS)**.
- Initially overseen by the **World Bank**.
- **Global Renewables and Energy Efficiency Pledge:** Commitments to:
  - **Triple global renewable energy capacity** to at least 11,000 GW by 2030.
  - **Double annual energy efficiency improvements** to over 4% by 2030.

Global Cooling Pledge: Aims to reduce **cooling-related emissions** by **68% globally** by 2050, with 66 national signatories.

Declaration to Triple Nuclear Energy: Targets tripling **global nuclear energy capacity** by 2050.

Nature Solutions Finance Hub for Asia & the Pacific

- **Launched By:** Asian Development Bank (ADB) during COP28 (Dubai)
- **Objective:** Mobilise finance for nature-based solutions (NbS) to support biodiversity conservation, ecosystem restoration, and climate resilience in Asia-Pacific.
- **Investment Target:** At least USD 2 billion for nature-based projects.
- **Key Features:**
  - Focus on private capital mobilisation and capital-market instruments
  - Use of blended finance, guarantees, and risk-mitigation tools
  - Support for policy frameworks, capacity building, and project pipelines

Major Engagements of India at COP28

Green Credit Initiative: Incentivizes **pro-planet actions** like reforestation on degraded lands and river catchment areas to restore ecosystems.

Leadership Group for Industry Transition (LeadIT 2.0): Promotes inclusive industry transitions through **low-carbon technology** development and financial support for emerging economies.

Global River Cities Alliance (GRCA)

- Led by India's **National Mission for Clean Ganga (NMCG)** to promote sustainable **river-centric development**.
- Encourages **knowledge sharing**, river-city collaborations, and adoption of best practices.

Quad Climate Working Group (QCWG):

- Focuses on empowering **local communities** and **regional governments** to foster **sustainable lifestyles**.

Declaration on Climate and Health

- **India's Stand:** India refrained from signing the Declaration at COP28.
- **Nature of Declaration:** Non-binding; encourages voluntary actions such as-
- Measuring health-sector emissions
- Preparing action plans
- Promoting low-carbon health systems, active mobility, and sustainable diets

COP29 (Baku, Azerbaijan) Major Outcomes

New Climate Finance Goal

- Adoption of the **New Collective Quantified Goal on Climate Finance (NCQG)** to triple finance for developing countries to **USD 300 billion/year by 2035**, up from USD 100 billion.
- General call for scaling climate finance to **USD 1.3 trillion/year by 2035** from all sources, led by developed countries.
- It provides for the following mechanism for climate finance and emissions reduction.

Carbon Markets Agreement

- Finalized mechanisms for **carbon markets** under **Articles 6.2 and 6.4 of the Paris Agreement:**
  - **Article 6.2:** Allows country-to-country carbon credit trading through bilateral agreements.
  - **Article 6.4:** Introduces a centralised UN-managed carbon offset and trading system.

Declaration on Reducing Methane

- Over 30 countries signed the **Declaration on Reducing Methane from Organic Waste** (India excluded).
- Focused on five areas: **NDCs**, regulation, data, finance, and partnerships.
- Aims to reduce methane emissions, which contribute to 20% of global emissions.

Indigenous Peoples and Local Communities

- Adoption of the **Baku Workplan** and renewal of the **Facilitative Working Group (FWG)** under the LCIPP.
- Prioritizes integrating **indigenous knowledge** into climate policies and enhancing indigenous participation.
- Progress to be reviewed in **2027**.

Gender and Climate Change

- Extension of the **Lima Work Programme on Gender (LWPG)** for 10 years.
- Reaffirms gender-responsive climate action, with a new gender action plan to be adopted at COP30.

Baku Harmoniya Climate Initiative for Farmers

- Launched in partnership with FAO to streamline climate initiatives for farmers and improve access to finance.

India's Stance at COP29

- **Opposition to NCQG**
  - India rejected the **USD 300 billion pledge**, terming it inadequate.
  - Advocated for **USD 1.3 trillion/year**, including **USD 600 billion in grants**, to meet developing countries' needs.
- **Article 9 of the Paris Agreement:** Criticised shifting the responsibility for climate finance to all actors, emphasizing the **historical accountability** of developed countries.
- **Solidarity with Vulnerable Nations:** Supported LDCs and SIDS, who protested against inadequate financial targets for addressing their climate challenges.

REDD AND REDD+

UN-REDD

- **Establishment:** Created in 2008 in response to the UNFCCC decisions on the Bali Action Plan and REDD.
- **Programme Focus:** The UN Programme on Reducing Emissions from Deforestation and Forest Degradation (UN-REDD).
- **Headquarters:** Geneva, Switzerland.
- **Membership:** 64 Partner Countries.
- **Role:** Engages in the conservation, sustainable management of forests, and enhancement of forest carbon stocks in developing countries.
- **Collaboration:** It is a multilateral collaborative program initiated by the Food and Agriculture Organization (FAO), the United Nations Development Programme (UNDP), and the United Nations Environment Programme (UNEP).

REDD+

- **Nature:** A voluntary climate change mitigation approach developed by Parties to the United Nations Framework Convention on Climate Change (UNFCCC).
- **Partnership**: Collaborates with developing countries to assist them in establishing the technical capacities necessary for implementing REDD+ and meeting UNFCCC requirements for REDD+ results-based payments.
- **Scope:** Goes beyond deforestation and forest degradation, **aiming to incentivize developing countries to reduce emissions from these activities, conserve forest carbon stocks, sustainably manage forests, and enhance forest carbon stocks.**
- **Objective:** Broadens the focus to include sustainable forest management and enhancement of forest carbon stocks, beyond just emission reduction.
- **Supporting Initiatives:** Besides the UN-REDD Programme, other initiatives supporting countries engaged in REDD+ include the World Bank's Forest Carbon Partnership Facility, the Global Environment Facility, the Green Climate Fund, among others.
- **Global Effort:** Part of a global effort to address climate change by promoting sustainable forestry practices and protecting carbon-rich forests.

OTHER INITIATIVES

Forest Carbon Partnership Facility (FCPF)

- **Global Partnership**: Involving governments, businesses, civil society, and Indigenous Peoples, primarily focusing on activities related to REDD+ (Reducing Emissions from Deforestation and Forest Degradation).
- **Functionaries:** The World Bank serves as the trustee and secretariat, with additional delivery partners such as the Inter-American Development Bank and UNDP under the Readiness Fund, responsible for providing REDD+ readiness support.

Climate and Clean Air Coalition (CCAC)

- **Establishment:** Formed in 2012, CCAC is a partnership involving nations, UNEP, and various stakeholders dedicated to protecting the climate by reducing short-lived climate pollutants **(SLCPs). SLCPs** include substances like **black carbon, methane, tropospheric ozone, and hydrofluorocarbons (HFCs).**
  - Despite their short atmospheric lifetimes, SLCPs can have a potent warming effect.
- **Benefits of Reducing SLCPs**
  - Preventing crop losses by reducing methane and black carbon emissions.
  - Slowing down the expected warming **by approximately 0.5°C by 2050,** contributing to the Paris Agreement's 2°C target.

BioCarbon Fund Initiative for Sustainable Forest Landscapes (ISFL)

A multilateral fund managed by the World Bank, aiming to promote reduced greenhouse gas emissions from deforestation, forest degradation, and sustainable agriculture.

Cool Coalition

Launched in 2019, it seeks to accelerate action toward clean and efficient cooling, led by UNEP, Climate and Clean Air Coalition, Kigali Cooling Efficiency Program, and Sustainable Energy for All. India is a member of the Cool Coalition.

GHG Protocol

Develops standards, tools, and training for tracking progress towards climate goals, focusing on measuring and managing greenhouse gas emissions. It is developed by the World Resources Institute (WRI) and the World Business Council for Sustainable Development (WBCSD)

Global Climate Change Alliance + (GCCA+)

An EU initiative supporting vulnerable countries, particularly Small Islands Developing States (SIDS) and Least Developed Countries (LDCs), in increasing resilience to climate change.

Global Alliance for Climate-Smart Agriculture (GACSA)

Promoted by FAO, it works towards improving food security, nutrition, and resilience in the face of climate change. Launched in 2014 during the UN Climate Summit.

Arctic Council

An intergovernmental forum promoting cooperation among Arctic states, Indigenous communities, and other inhabitants on common Arctic issues, particularly sustainable development and environmental protection.

EU Sets New Climate Goal for 2040

The European Parliament has recently approved the Net-Zero Industry Act to enhance net-zero technology production within the European Union.The European Union aims to be climate-neutral by 2050 – an economy with net-zero greenhouse gas emissions. It is part of the European Green Deal and is a legally binding target.

India's Climate Action

In addition to India's active participation and leadership in global climate initiatives, India also has launched the National Action Plan on Climate change to combat climate change.

National Action Plan on Climate Change (NAPCC)

India's **National Action Plan on Climate Change (NAPCC)** was launched in **2008** to address climate change while promoting sustainable development. It outlines India's strategy for tackling climate change and enhancing adaptive capacity. The NAPCC consists of **eight core missions**, which focus on both mitigation and adaptation across different sectors.

Missions under National Action Plan on Climate Change (NAPCC)

Mission	Objective	Ministry Responsible
❖ **National Solar Mission (NSM)**	Promote solar energy and increase its share in the energy mix.	Ministry of New and Renewable Energy (MNRE)
❖ **National Mission for Enhanced Energy Efficiency (NMEEE)**	Improve energy efficiency across sectors, including industry and transport.	Bureau of Energy Efficiency (BEE) under Ministry of Power

❖ **National Mission on Sustainable Habitat (NMSH)**	Promote energy-efficient and sustainable practices in urban areas.	Ministry of Housing and Urban Affairs (MoHUA)
❖ **National Water Mission (NWM)**	Conserve water resources and improve water use efficiency.	Ministry of Jal Shakti
❖ **National Mission for Sustainable Agriculture (NMSA)**	Promote sustainable agriculture practices, water-efficient irrigation, and organic farming.	Ministry of Agriculture and Farmers Welfare (MoA&FW)
❖ **National Mission on Green India (GIM)**	Increase forest and tree cover, enhance biodiversity, and protect ecosystems.	Ministry of Environment, Forest and Climate Change (MoEFCC)
❖ **National Mission for Sustaining the Himalayan Ecosystem**	Promote ecological resilience and protect key ecosystems in the Himalayan region.	Ministry of Science and Technology
❖ **National Mission on Strategic Knowledge for Climate Change (NMSKCC)**	Strengthen research, data collection, and technological capacity to address climate change.	Ministry of Earth Sciences (MoES)

Intergovernmental Panel on Climate Change (IPCC)

- **Established** in 1988 by the **World Meteorological Organization (WMO)** and **United Nations Environment Programme (UNEP)**.
- **Purpose**: To assess climate change science and provide policymakers with insights on:
  - The scientific basis of climate change.
  - Its impacts, future risks, and adaptation/ mitigation strategies.
- **Role**
  - Supports climate-related policy development.
  - Informs negotiations under the **United Nations Framework Convention on Climate Change (UNFCCC)**.

IPCC Assessment Reports

- Comprehensive global scientific reports on climate change.
- Six assessment cycles completed with the following reports:
  1. **First Assessment Report (FAR)** – 1990.
  2. **Second Assessment Report (SAR)** – 1995.
  3. **Third Assessment Report (TAR)** – 2001.
  4. **Fourth Assessment Report (AR4)** – 2007.
  5. **Fifth Assessment Report (AR5)** – 2014.
  6. **Sixth Assessment Report (AR6)** – 2023.

The IPCC Sixth Assessment Report (AR6) Synthesis Highlights

- It flags the urgent need for action to address the escalating impacts of climate change
- It states that the global temperatures have already risen by 1.1°C above pre-industrial levels, with increasing frequency of extreme weather events and irreversible changes such as sea-level rise and biodiversity loss.
- Vulnerable populations, particularly in developing countries, face disproportionate risks, including food and water insecurity, health challenges, and ecosystem degradation.
- Without immediate and deep reductions in greenhouse gas emissions, global warming is likely to exceed 1.5°C, leading to severe and widespread consequences.
- The report calls for rapid emission reductions, global net-zero CO_2 emissions by 2050, and significant investments in renewable energy and carbon removal technologies.
- Adaptation efforts, such as climate-resilient infrastructure and nature-based solutions, must be scaled up urgently, though some regions are nearing adaptation limits.
- Bridging the finance gap, particularly for developing nations, and ensuring equity and justice in climate actions are critical.
- Achieving these goals requires transformative changes across energy, land use, and urban systems, underpinned by strong international cooperation and adherence to the Paris Agreement

Current Status

- The IPCC is in its **Seventh Assessment Cycle (AR7)**, continuing its critical work on climate change research and guidance.

CLIMATE FINANCE

Climate finance involves local, national, or transnational funding from public, private, and alternative sources to support actions that address climate change, including:

- **Mitigation**: Reducing greenhouse gas emissions.
- **Adaptation**: Enhancing resilience to climate impacts.

It aligns with the principle of **"Common but Differentiated Responsibility and Respective Capabilities" (CBDR-RC)**, which mandates financial assistance from developed to developing countries, recognizing their varying capabilities and responsibilities.

Global Climate Financing Mechanisms

- **Green Climate Fund (GCF)**
  - Established in 2010 to reduce GHG emissions in developing countries and support climate adaptation.
  - The **COP in Cancun, Mexico (COP 16)**, decided to establish GCF.It's HQ is in Incheon,South Korea.
  - Equal emphasis on adaptation and mitigation.
  - The World Bank serves as the GCF's trustee.
- **Adaptation Fund (AF)**
  - Created under the **Kyoto Protocol in 2001.**
  - Committed over $532 million for adaptation and resilience activities.
  - In India, the **National Bank for Agriculture and Rural Development (NABARD)** is the National Implementing Entity (NIE) for the AF. This means that NABARD is responsible for the overall management of the projects and programs financed by the AF
- **Global Environment Facility (GEF)**
  - Operating since 1994 to fund clean energy and climate adaptation projects.
  - Manages the Special Climate Change Fund (SCCF) and Least Developed Countries Fund (LDCF).

Special Climate Change Fund (SCCF): Managed by the GEF, it provides resources for adaptation, technology transfer, and capacity building in developing nations.

Least Developed Countries Fund (LDCF): Specifically targets the adaptation needs of Least Developed Countries (LDCs), helping implement National Adaptation Programs of Action (NAPAs).

Hosts financial Mechanism for Conventions: CBD, UNFCCC, UNCCD, Stockholm Convention, and Minamata Convention

- **Loss and Damage Fund**
  - Established at the **2022 UNFCCC Conference (COP27) in Egypt.**
  - Operationalized to compensate nations suffering both economic and non-economic losses caused by climate change.
  - Priority funding for **Least Developed Countries (LDCs)** and **Small Island Developing States (SIDS)** facing the brunt of climate change.
  - LDF is **overseen by a Governing Board** that determines how the fund's resources are disbursed, with the **World Bank serving as** the **interim trustee** tasked with **hosting the fund for four years.**

Climate Finance at COP29 (Baku- Finance COP)

- **New Climate Finance Goal**
  - Adoption of the **New Collective Quantified Goal on Climate Finance (NCQG)** to triple finance for developing countries to **USD 300 billion/year by 2035**, up from USD 100 billion.
  - General call for scaling climate finance to **USD 1.3 trillion/year by 2035** from all sources, led by developed countries

Climate Financing and India

- **National Initiatives**
  - **National Adaptation Fund for Climate Change (NAFCC)**: Established in 2015 to support adaptation efforts in vulnerable states and UTs.
  - **National Clean Energy Fund**: Funded by a coal tax to promote clean energy technologies.
- **Programmes and Mechanisms**
  - Compensatory Afforestation Fund Management and Planning Authority (CAMPA).
  - Disaster Management Fund.
- **Policy and Governance**
  - A Climate Change Finance Unit under the Ministry of Finance guides climate finance policies and global engagements.

COP30 Climate Summit (The Belém Package)

- The summit focused heavily on **implementation over new targets**, adopting a package of 29 negotiated decisions.
- **Global Mutirão Agreement & Platform:** A compromise pact prioritizing international cooperation and delivery rather than forcing new mandatory targets. Brazil launched a digital platform to track collective action in energy, finance, and trade.
- **Just Transition Mechanism (JTM / BAM):** Formally established to support workers and economies shifting away from fossil fuels, though it lacks guaranteed financial backing.
- **Tracking and 1.5°C Alignment:** Launched the Global Implementation Tracker and the Belém Mission to 1.5°C to closely monitor whether national climate plans (NDCs) match the 1.5°C warming pathway.
- **Adaptation Progress:**
  - Launched the NAP (National Adaptation Plan) Implementation Alliance.
  - Agreed to **triple adaptation finance by 2030** (from 2025 levels).
  - Finalized 59 voluntary indicators under the Baku Adaptation Roadmap to track the Global Goal on Adaptation.
- **Tropical Forests Forever Facility (TFFF):** A flagship **payment-for-performance** model pioneered by

Brazil to reward countries for keeping tropical forests standing. Aiming to mobilize **$125 billion** ($1 billion kickstarted by Brazil).

- **Belém 4x Pledge:** A goal to quadruple the use of sustainable fuels (hydrogen, biofuels, biogas, e-fuels) by 2035 compared to 2024 levels.
- **Social & Health Pledges:**
  - Belém Health Action Plan: Aims to build climate-resilient health systems focused on equity and community participation.
  - Hunger, Poverty & Climate Declaration: Signed by 43 nations and the EU to protect vulnerable communities through social safety nets and crop insurance.
  - Gender Action Plan (GAP): Designed to increase the participation of women in climate governance.
- **India's Position & Key Statements:**India aligned closely with the BASIC (Brazil, South Africa, India, China) and LMDC (Like-Minded Developing Countries) blocs, focusing on **equity and climate justice**.
- **Finance as a Legal Obligation:** India demanded predictable, grant-based climate funding rather than loans. It called on developed countries to honor **Article 9.1 of the Paris Agreement** and mobilize the **$1.3 trillion** target set at COP29.
  - The Gap: India highlighted that developing nations need $310–365 billion annually for adaptation, while current global flows stall around just $26 billion.
- **CBDR-RC Principle:** Reaffirmed that historical polluters must lead emission cuts. India explicitly stated that the burden of mitigation must not be shifted to those least responsible.
- **Pushback Against Trade Barriers:** India and China strongly opposed unilateral trade barriers, specifically targeting the **EU's Carbon Border Adjustment Mechanism (CBAM)**, labeling it a discriminatory trade barrier disguised as climate action.
- **Support for the Presidency:** India formally welcomed the Just Transition Mechanism, the progress on the Global Goal on Adaptation, and Brazil's inclusive, consensus-driven leadership.
- **Major Shortcomings & Gaps:**Despite the high volume of pledges, several critical issues were left unaddressed:-
- **No Fossil Fuel Phase-Out:** The final Belém Package completely avoided establishing a concrete roadmap or commitment to phase out fossil fuels.
- **The "Who Pays?" Dilemma:** While adaptation funding goals were tripled, negotiations failed to secure legally binding clarity on which developed nations will actually provide the money.
- **The Just Transition Funding Void:** The newly minted Just Transition Mechanism lacks a dedicated, predictable financial stream, threatening its real-world implementation.
- **Submission Delays:** Several major global polluters—including India—**delayed submitting their updated NDCs**, widening the global emissions gap and slowing momentum.
- **Accountability Gap:** Most newly announced targets lack concrete timelines, enforcement systems, or strict accountability frameworks.

CAMPA

- The CAMPA funds are utilised for compensating the loss of forest land and ecosystem services by raising of compensatory afforestation, improving quality of forests through assisted natural regeneration, enrichment of biodiversity, improvement of wildlife habitat, control of forest fire, forest protection and soil and water conservation measures.
- **The Compensatory Afforestation Fund (CAF Act), 2016 and Rules, 2018** provide elaborate guidelines and activities for utilization of CAMPA Fund. CAMPA also supports creation of nurseries for multiplication of quality planting material of locally suitable plant species.The monitoring and evaluation of CAMPA activities is provided in the CAF Act, 2016.
- **The act also** provides for audit of the accounts of both National and States/UTs CAMPA Authorities by the Comptroller and Auditor- General of India (C&AG).

CONSTITUTIONAL PROVISIONS

- The original Indian **Constitution lacked environmental safety provisions**.
- **42nd Amendment (1976):** added citizens' duty to protect the environment under **Article 51A(g)** while **Article 48A (To protect and improve the environment and to safeguard the forests and wildlife of the country.)mandates State action.**
- **Article 21** guarantees the right to a healthy environment.
- The Department of Environment (1980) became the Ministry of Environment and Forests (1985), then the Ministry of Environment, Forests and Climate Change (2014).

POLLUTION RELATED LAWS

The Water (Prevention and Control of Pollution) Act of 1974

- Defined terms like **Pollution, sewage, effluent, stream and boards.**
- **Regulatory authority**: Led to the formation of State Pollution Control Boards (**SPCBs**), Central Pollution

Control Board (**CPCB**) and grant them power to test equipment and samples for the purpose of analysis.

- The **1988 amendment act empowered SPCB and CPCB to directly close a defaulting industrial plant.**

The Water (Prevention and Control of Pollution) Amendment Act, 2024

- The central government will prescribe the manner of nomination and the terms and conditions of service of the chairman
- It specifies that the central government, in consultation with the CPCB, may exempt certain categories of industrial plants from obtaining such consent.
- It adds that the central government may issue guidelines for the grant, refusal, or cancellation of consent granted by the SPCB.
- The Act decriminalises several violations, and instead imposes penalties between ₹10,000 and ₹15 lakh

Central Pollution Control Board (CPCB)

- **Statutory body** constituted under the **Water (Prevention and Control of Pollution) Act, 1974.**
- Entrusted more **powers and functions under the Air (Prevention and Control of Pollution) Act, 1981.**
- Provides technical services to the MOEFCC under provisions of the Environment (Protection) Act, 1986.
- Oversees the National Air Monitoring Programme (NAMP) and Water Quality Monitoring (WQM). the Central Pollution Control Board (CPCB), an Air Quality Index (AQI). (RAS 2024)

AQI Categories (CPCB):

- 0–50: Good
- 51–100: Satisfactory
- 101–200: Moderate
- 201–300: Poor
- 301–400: Very Poor
- 401–500: Severe

The Air (Prevention and Control of Pollution) Act of 1981

- Enacted under **Article 253** to implement the **1972 Stockholm conference** decisions.
- Defined terms like **Air Pollution and Air Pollutants**
- Central and state **water boards** have been entrusted with the **task of controlling and preventing air pollution.**
- The Act granted power to SPCBs to **test equipment and take samples**.
- The 1987 amendment extended the Act **to include noise pollution.**
- The **1988 amendment empowered SPCBs and CPCB to close defaulting industrial plants.**

Inorganic Gaseous Pollutants (RAS 2013)

- Carbon dioxide (CO_2), carbon monoxide (CO), sulfur dioxide (SO_2), nitric oxide (NO), nitrogen dioxide (NO_2), and hydrogen sulfide (H_2S) are collectively known as Inorganic Gaseous Pollutants.
- These pollutants are mainly produced as by-products of fuel combustion and are common components of air pollution.
- Combustion appliances are the major sources of inorganic gaseous pollutants in both indoor and outdoor environments.
- Major sources include unvented and vented space heaters, tobacco products, wood-burning stoves, fireplaces, furnaces, gas stoves, and ovens.

Environment (Protection) Act of 1986

The **Environment (Protection) Act, 1986 (EPA)** provides a framework for safeguarding the **environment**, addressing **environmental threats**, and ensuring **swift responses** to such situations.

Background

Enacted to implement decisions from the **Stockholm Conference** aimed at **environmental improvement**. The Environment Protection Act (EPA) of 1986 was enacted to improve and protect India's environment in response to the Bhopal Gas Tragedy and gaps in environmental legislation

Powers of the Central Government

The Act grants **broad powers** to the **Central Government** to prevent **environmental pollution**, including:

- Establishing authorities to address **environmental issues** specific to different regions.
- Developing **national programs** for **pollution prevention** and **abatement**.
- Setting **standards** for **environmental quality** and **pollution control measures**.
- Issuing directions to:
  - Close or regulate **industries**, **operations**, or **processes**.
  - Control the supply of services such as **electricity** or **water**.
- **Authority to issue direct orders, including orders to close, prohibit or regulate any industry.**
- Power of **entry for examination, testing of equipment and other purposes and power to analyze the sample of air, water, soil** or any other substance from any place.
- Preparation of codes, guides and manuals.
- Such other matters as the **central government deems necessary or expedient for the purpose of securing the effective implementation** of the act.

Offences and Penalties

- **Offences:** Non-compliance or violation of the Act's provisions constitutes an offence.
- **Cognizance:** Courts can only act on complaints filed by the **Central Government**, its authorized authority, or individuals providing 60-day prior notice to the Government.
- **Penalties:**
  - For violation: Imprisonment up to 5 years, a fine up to ₹1,00,000, or both.
  - For continued violations: Additional fine of ₹5,000 per day.
  - For extended violations (over one year): Imprisonment up to 7 years.

FOREST CONSERVATION AND RELATED PROVISIONS

Indian Forest Act 1865

The act allowed the British government to declare any land covered with trees as a government forest.

Indian Forest Act 1878

This act classified forests into **Reserve, protected and Village forest.**

Indian Forest Act 1927 (IFA, 1927)

The act is largely based on previous Indian Forest Acts implemented under the British. The most famous is the Indian Forest Act of 1878.

- Provides a legal framework for the **protection and management** of forests and duty leviable on Timber.
- Provides for a **procedure** to be followed for declaring an area to be Reserve/Protected/Village Forest **(Degree of protection: Reserved forests > Protected forests > Village forests)**
  - **Reserve Forest (RF)**: **State government** may constitute any forest land or wasteland as reserved forest. All activities are prohibited unless permitted in RFs.
  - **Protected Forest (PF): State government** may constitute any forest land or wasteland not included in Reserve Forest as a Protected Forest. All activities are permitted unless prohibited in PFs.
  - **Village Forest:** Area of land constituted as a reserved forest that the state government can assign to a village community.
- The **Forest Settlement Officer** is appointed to **inquiry into and determine the existence, nature and extent of any rights.**
- **Recently Amended the definition of tree** to remove the word bamboos. It means bamboo growing in non-forest areas will be waived off the requirement of permission for its felling or transportation for economic use.

Forest (Conservation) Act 1980 (FCA 1980)

- **Prior approval of the Central Government** is required for diversion of forestlands for non-forest purposes.
- An Advisory Committee constituted under the Act advises GOI on these approvals.
- The Act deals with the **4 categories of forests**-Reserved forests, Village forests, Protected forests and Private forests.
- **1992 Amendment:** It provisioned for allowing some non-forest activities in forests, without cutting trees or limited cutting with prior approval of the Central Govt.
- **It gives states the responsibility and power** to identify and notify forests.
- The act **recognised the concept of Deemed Forest (**areas that are not officially classified as forest but are ecologically important and have forest-like characteristics) Such areas are included in this act.

Forest (Conservation) Amendment Act, 2023

The **Forest (Conservation) Amendment Act, 2023**, enacted in July-August 2023, aims to **clarify** the scope of **deemed forests** and address concerns related to **forest land management**.

Features	Details
Scope of Forest Land Under the Act	**Included Categories:** ❖ Land declared as forest under the Indian Forest Act or any other law, or notified as a forest after October 25, 1980. ❖ Land converted from forest to non-forest use before December 12, 1996.
Exemptions from the Act	**Land Use Exemptions:** ❖ Up to 0.10 hectares for connectivity along roads and railways. ❖ Up to 10 hectares for security-related infrastructure. ❖ Up to 5 hectares for public utility projects in Left Wing Extremism Affected Districts. **Strategic Projects:** ❖ Exemptions for national security projects within 100 km of international borders, the Line of Actual Control (LAC), and the Line of Control (LoC).

Permitted Activities in Forest Land	❖ Activities for conservation, management, and development. ❖ Exemptions for specific activities, such as zoos, ecotourism facilities, silvicultural operations, and certain surveys.
Assignment/Leasing of Forest Land	**Prior Approval Requirement:** ❖ Central government approval is mandatory for assigning forest land to any entity, not limited to private organizations. **Regulatory Oversight:** ❖ The central government has authority to define terms and conditions for such assignments.

The National Forest Policy 1988

- Envisages to have a minimum of one-third of the total land area of the country under forest or tree cover.
- As per India State of Forest Report, **Forest cover is defined as: All lands, more than one hectare in area, with a tree canopy density of more than 10 percent irrespective of ownership and legal status.** Such lands may not necessarily be a recorded forest area. It also includes orchards, bamboo and Palm.

Forest area vs Forest cover

Aspect	Forest Area	Forest Cover
Definition	Geographic areas recorded as forests in government records.	Lands with a tree canopy density of more than 10% and an area of more than one hectare.
Legal Basis	Denotes the legal status of land as forests under laws like the Indian Forest Act, 1927.	Mentioned as such in the state of Forest Report
Based on	Legal/Administrative definition	Physical characteristics
Constituents	Includes Reserved Forests (RF), Protected Forests (PF), and areas recorded as forests in revenue or state/local laws. May include areas with vegetation cover, blanks, or density less than 10%.	Includes natural forests, plantations, and areas outside recorded forests with tree canopy density greater than 10%.
Scope	Based on government records and administrative classification.	Based on tree canopy density and spatial assessment.
Additional Note	Not all recorded forest areas have vegetation cover or sufficient density.	Areas outside recorded forests with more than 10% canopy density are also included in forest cover assessment.

Forest Cover under Indian state of Forest report can be classified into the following categories.

Forest Type	Description
Very Dense Forest	All lands with tree cover (including mangrove cover) of canopy density of **70% and above.**
Moderately Dense Forest	All lands with tree cover (including mangrove cover) of canopy density between **40% and 70%.**
Open Forest	All lands with tree cover (including mangrove cover) of canopy density between **10% and 40%.**
Scrub	All forest lands with poor tree growth, mainly of small or stunted trees, having **canopy density < 10%.**

Forest Rights Act, 2006 (FRA 2006)

The Act provides for the restitution of deprived forest rights across India. It provides for integrating conservation and people's livelihood rights and strengthening the local self-governance.

- For the first time FRA recognizes and secures:
  - **Community Rights** in addition to their Individual Rights
  - **Right to intellectual property and traditional knowledge** related to biodiversity and cultural diversity.
  - Rights of displaced communities and rights over developmental activities.
- **Applicable to Tribal and Other Traditional Forest Dwelling Communities**.
- The nodal agency for the implementation is the Ministry **of Tribal Affairs (MoTA)**
- Recognizes the **right of ownership access** to collect, use, and dispose of minor forest produce (FRA defines Minor Forest Produce to include non-timber forest produce of plant origin) by tribals.
- Rights conferred under the Act shall be **heritable but not alienable or transferable.**
- **National Parks and Sanctuaries have been included** along with Reserve Forest, and Protected Forests for the recognition of Rights.
- FRA **only recognises pre-existing rights** which are already being exercised by eligible persons in NPs and Sanctuaries.
- **Secures the tenure of existing forest dwellers**, but **no new rights** are being created.
- The FRA act identifies **4 types of rights:**
  - **Title Rights**: Gives right to ownership to land-farmed forest dwellers(max. of 4 hectares)
  - **Use rights**: Rights of the dwellers extend to extracting Minor Forest Produce, grazing areas, etc.
  - **Relief and development rights:** Rehabilitation in case of illegal eviction.
  - **Forest management rights**: Right to protect, regenerate or conserve or manage any community forest resource.
- **Criteria** and evidence for **Forest Dwelling Scheduled Tribes (FDST)** to claim rights under FRA:
  - Must be **ST** in an area.
  - Primarily resided in forest or land before Dec 2005
  - Depend on forest or forest land for livelihood needs
- **Criteria for other Traditional Forest Dweller (OFTD) to claim rights under FRA:**
  - Primarily resided in forest for 3 generations (75 years) before December 2005.
  - Depend on forest for livelihood needs.
  - If an OTFD village establishes its eligibility under the act, there is no need for every individual to establish its eligibility separately.
- **Gram Sabha:** Designated as the **competent authority for initiating the process of determining the nature and extent of individual or community forest rights.** Decisions can be appealed before a court.

Critical Wildlife Habitat Notification under FRA, 2006

- **2011 Guidelines by MoEFCC for Critical Wildlife Habitat**
  - To notify a CWH, the FRA **requires state governments to establish that the presence of right-holders is causing irreversible damage to wildlife and their habitats.**
  - **Gram Sabha's free informed consent** must be given before any relocation of right-holders is carried out.
- **2018 Guidelines by MoEFCC**
  - **Identification**: Chief Wildlife Warden of a state will notify a **7-member expert committee**, **chaired by a chief conservator of forest in charge** of a national park or sanctuary, for identification of CWH in an NP or sanctuary based on scientific and objective criteria relevant to the protected area.
  - The Expert Committee shall **issue a public notice 15 days in advance on the intention to notify CWH.**
  - Final decision will be taken by the Standing Committee of the National Board for Wildlife.

OTHER LAWS AND REGULATIONS

Biodiversity Act, 2002

The Biological Diversity Act, 2002, aims to:

- **Conserve** biological resources.
- **Promote** their sustainable use.
- **Ensure** fair and equitable sharing of benefits derived from their use with local communities.

Key Features

Prohibited Activities Without Approval

Approval from the National Biodiversity Authority (NBA) is required for:

- **Access to Biological Resources**: Research or commercial use of Indian biological resources.
- **Research Transfer**: Transferring research outcomes based on Indian biological resources.
- **Intellectual Property Rights (IPR)**: Claiming IPR on inventions based on Indian biological resources.

Key Functions

- **Conservation and Sustainable Use**: Supervise the sustainable use of resources and regulate financial investments.
- **Threatened Species**: Notify and regulate the conservation and rehabilitation of threatened species.
- **Repositories**: Designate institutions to store and manage biological resources.

Legal Provisions

- Offences under the Act are **cognizable and non-bailable**.
- Grievances related to benefit-sharing or regulatory orders are handled by the **National Green Tribunal (NGT)**.

Exemptions

- **Commodities**: Indian biological resources traded as commodities (limited to this purpose).
- **Traditional Uses**: Traditional knowledge and practices involving biological resources.
- **Collaborative Research**: Joint research projects with foreign institutions, subject to Central Government approval.
- **Agricultural Use**: Activities by farmers, livestock keepers, beekeepers, and traditional healers.

Regulatory and Institutional Framework

The Act establishes a 3 tier institutional framework at the national, state and local levels.

Entity	Established/Type	Functions
National Biodiversity Authority (NBA)	Established at the National level	Promote biodiversity conservation and sustainable use- Regulate access and benefit-sharing- Oppose unauthorized IPR claims on Indian resources abroad- Advise on biodiversity heritage sites
State Biodiversity Boards (SBBs)	Established by State Governments (Section 22 of the Act)	Advise State Governments on biodiversity conservation- Regulate commercial use and resource surveys
Biodiversity Management Committees (BMCs)	Constituted by local bodies (Section 41 of the Act)	**Prepare People's Biodiversity Registers** documenting local biological resources- Promote conservation and sustainable use of biodiversity

Biodiversity Heritage Sites (BHS)

Biodiversity Heritage Sites (BHS) are areas recognized for their exceptional ecological, faunal, floral, geological, or natural significance. Designated under the **Biological Diversity Act, 2002** in India, these sites aim to conserve and protect unique ecosystems, species, and habitats while promoting sustainable management. Nallur Tamarind Grove in Bengaluru, Karnataka was the first Biodiversity Heritage Site of India, declared in 2007. These are **notified** by State Governments.

Coastal Regulation Zone (CRZ) Rules

- Coastal stretches of seas, bays, estuaries, creeks, rivers and back waters which are **influenced by tidal action** were declared "Coastal Regulation Zone" (CRZ) in 1991. The regulation zone has been defined as the **area <500 m from the high-tide line.**
- **National Coastal Zone Management Authority (NCZMA) and State Coastal Zone Management Authority (SCZMA):** Established for enforcement and monitoring of the CRZ rules. These authorities have been delegated **powers under the Environmental (Protection) Act, 1986.** The implementation of CRZ rules is done by state governments through their SCZMA. The states need to frame their own coastal zone management plans in accordance with the central Rules.

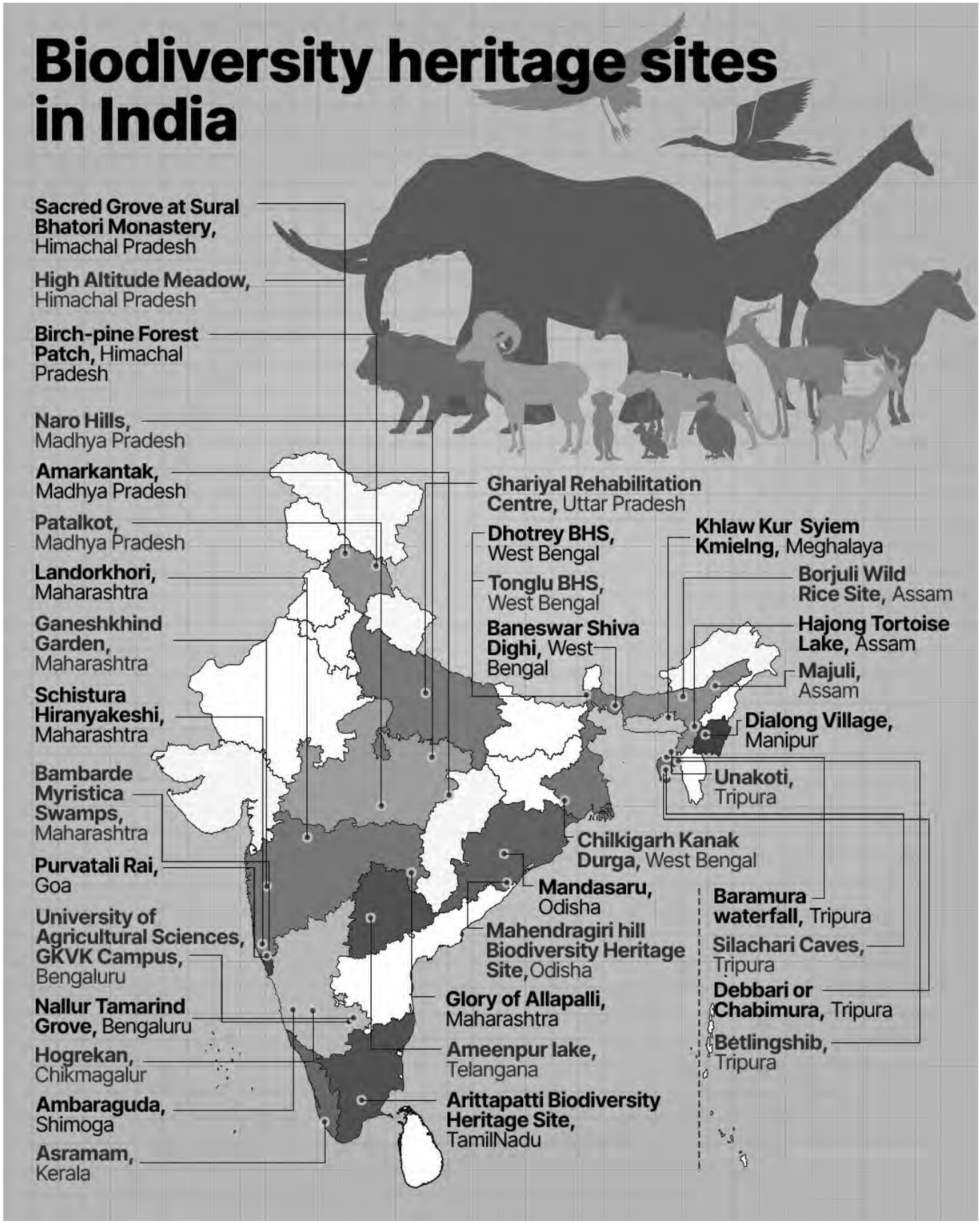
Coastal Regulation Zone (CRZ) Rules 2011

The demarcation of zones is as follows:

- **CRZ-I**: **Ecological sensitive area**. **No new construction** is permitted **except for a few specified most essential activities** like support activities for Atomic Energy Plants and Defense requirements, **facilities required for disposal of treated effluents and extraction of natural gases and salt harvesting.**
- **CRZ-II:** Area that has been **developed up to or close to the shore line** which includes the designated urban areas that are substantially built up. **Buildings permitted only on the landward side** of the existing authorized structures.
- **CRZ-III:** Areas **not CRZ-I or CRZ-II,** like rural and less built-up urban areas, **are relatively undisturbed.** Within 200 meters of the High Tide Line (HTL), a "No Development Zone" prohibits construction except for repairs. **In CRZ-III, from 200 to 500 meters of HTL, development of vacant plots is allowed for dwelling units, hotels, or beach resorts under specific conditions.**

❖ **CRZ-IV:** The **activities impugning on the sea and tidal influenced water bodies** will be regulated **except for traditional fishing and related activities** undertaken by local communities. **No untreated sewage, effluents, pollution from oil drilling** shall be let off or dumped.

Biodiversity Heritage Sites in India



CRZ Rules 2018

- For the **CRZ-III (Rural) areas**, two separate categories-
  - **CRZ-IIIA:** For areas with a population density of 2,161 per sq km as per the 2011 Census, the no-development zone is now 50 m from the high-tide level, as against the 200 m stipulated earlier.
  - **CRZ-IIIB:** For areas with population density <2,161 per sq km continue to have a no-development zone extending up to 200 m from the high-tide line.
- **No-development zone:** 20 m for all islands close to the mainland coast, and for all backwater islands in the mainland.
- **Tourism infrastructure permitted in coastal areas**: Temporary tourism facilities such as shacks, toilet blocks, change rooms, drinking water, etc. have been permitted.
- **CRZ Clearances**: Projects which are located in the **CRZ-I and CRZ IV will be dealt with for CRZ clearance by the MoEFCC.** The powers for clearances with respect to **CRZ-II and III have been delegated at the State level.**

Integrated Coastal Zone Management Plan (ICZM)

- It is a process for the management of the coast using an integrated approach, regarding all aspects of the coastal zone, including geographical and political boundaries, in an attempt to achieve sustainability.
- The concept was born in 1992 during the Earth Summit of Rio de Janeiro.
- It is a **World Bank assisted** project and is being implemented Union Ministry of Environment,
- Forests and Climate Change (MoEFCC).

Beach Environment & Aesthetics Management Services (BEAMS)

- It is one of the initiatives under the Integrated Coastal Zone Management Programme.
- Launched by the Society of Integrated Coastal Management (SICOM) and the Union Ministry of Environment, Forest and Climate Change (MoEFCC).
- It aims to develop and maintain eco-friendly, clean, and safe beaches to boost sustainable tourism
- The initiative aims to help Indian beaches meet the Blue Flag Standards, an international eco-label for clean and sustainable beaches.

Blue Flag Beaches

'Blue Flag' annual certification is an **eco-label certification** that a **beach, marina, or sustainable boating tourism operator can obtain**.

- It was **started in France** in 1985 and in areas out of Europe in 2001. It is **awarded by Denmark based Foundation for Environment Education (FEE).**
- Blue Flag Beaches are selected **based on 33 parameters.** These criteria are divided into **4 major heads- Water quality, Environmental management, Environmental Education, and Safety.**
- The jury that selects Blue Flag beaches comprises members of the: **UNEP**, UN World Tourism Organization (**UNWTO**), Foundation for Environmental Education (**FEE**) and **IUCN**. **Spain** has the highest number of Blue Flag beaches (729).

Blue Flag Beaches of India: There are 12 Blue Flag certification beaches in India. Chandrabhaga beach (or the Golden beach) in Odisha is the first beach in India as well as in Asia to win the Blue Flag certification. The Minicoy Thundi beach and Kadmat beach, located in Lakshadweep Islands are recent receivers of eco-label 'Blue Flag'.

State wise list

S.No.	Beach Name	State/UT
1	Shivrajpur Beach	Gujarat
2	Ghoghla Beach	Diu
3	Kasarkod Beach	Karnataka
4	Padubidri Beach	Karnataka
5	Kappad Beach	Kerala
6	Rushikonda Beach	Andhra Pradesh
7	Golden Beach	Odisha
8	Kovalam Beach	Tamil Nadu
9	Eden Beach	Puducherry
10	Radhanagar Beach	Andaman & Nicobar Islands
11	Thundi Beach	Lakshadweep
12	Kadmat Beach	Lakshadweep

Rules for Hazardous Microorganisms/ Genetically Engineered Organisms or Cells 1989

Aims to protect the environment, nature, and health (biosafety) in connection with application of gene technology and microorganisms.

Presently there are six committees

- **Recombinant DNA Advisory Committee (RDAC)**: **Advisory body** that recommends safety regulations in recombinant research and applications.
- **Review Committee on Genetic Manipulation (RCGM)**: Established under the Department of Biotechnology, Ministry of Science and Technology, to monitor the safety related aspects in respect of on-going research projects.
- **Genetic Engineering Appraisal Committee (GEAC)**: **Statutory body** constituted in the MoEFCC under 'Rules 1989', **under the Environment Protection Act, 1986.**

- **State Biotech Coordination Committee (SBCC)**: Monitoring Role. It also has powers to inspect, investigate and take punitive action in case or violations of statutory provisions.
- **District Level Committees (DLCs): Role in** monitoring the safety regulations in installations engaged in the use of GMOs/hazardous microorganisms and its applications in the environment.
- **Institutional Biosafety Committee (IBSC)** is established to GMO research & to interface with RCGM in regulating it.

Protection Against Chemical Disasters

- **Environment Act of 1986:** Gives powers to the central government to undertake measures for improving the environment and set standards and inspect industrial units.
- **Bhopal Gas Leak (Processing of Claims) Act, 1985:** Gives powers to the central government to secure the claims arising out of or connected with the Bhopal gas tragedy.
- **The Public Liability Insurance Act, 1991**: To provide relief to persons affected by accidents that occur while handling hazardous substances.
- **The National Environment Appellate Authority Act, 1997:** To hear appeals regarding the restriction of areas in which any industries, operations or processes or class of industries shall not be carried out or shall be carried out subject to certain safeguards under the Environment (Protection) Act, 1986.
- **National Green Tribunal, 2010:** Establishment of the National Green Tribunal for effective and expeditious disposal of causes related to environmental protection and conservation of forests.

Strict vs Absolute Liability Principle

- **Strict Liability Principle:** A party is **not liable and need not pay compensation** if a hazardous substance escapes its premises by accident or by an 'act of God'.
- **Absolute Liability Principle**: a party in a hazardous industry cannot claim any exemption. It has to **mandatorily pay compensation**, whether or not the disaster was caused by its negligence.
  - The **National Green Tribunal Act of 2010** incorporates the absolute liability principle and mandates its application even if the disaster caused is an accident. Absolute liability thus provides no exemptions and is **part of Article 21 (Right to Life).**

National Green Tribunal Act, 2010

- Mandated to **dispose of the cases within 6 months** of their respective appeals.
- It was enacted in consonance with Right to healthy environment, construed as a part of Right to life under Article 21.
- **Principal Bench: New Delhi**
- **Regional benches: Pune** (Western Zone Bench), **Bhopal** (Central Zone Bench), **Chennai** (Southern Bench) and **Kolkata** (Eastern Bench)
- **Members:** Currently **10 expert members and 10 judicial members though the act allows for up to 20 of each.** Every bench of the tribunal must consist of **at least 1 expert member & 1 judicial member.**
- **Chairman:** Serving/ retired Chief Justice of a HC or a judge of the SC of India. The Chairman of the tribunal also serves as a judicial member.
- **Jurisdiction:** Original Jurisdiction on matters of "**substantial question relating to environment"** and "**damage to environment due to specific activity**".
- **Powers: Binding Orders**, **Power to grant relief in the form of compensation and damages** to affected persons. Right **to hear all civil cases relating to environmental issues** and questions that are linked to the implementation of laws listed in Schedule I of the NGT Act.
  - These include the following: **The Water Act, 1974; The Water Cess Act, 1977; The Forest Act, 1980; The Air Act, 1981; The Environment Act, 1986; The Public Liability Insurance Act, 1991; The Biological Diversity Act, 2002 (Not WPA 1972, Indian Forest Act, 1927**).
- **Principles of Justice:** Not bound by the procedure laid down under the Code of Civil Procedure, 1908, Indian Evidence Act 1872 but shall be **guided by principles of natural justice.**
- While passing Orders/decisions/awards, the NGT will **apply the principles of sustainable development,** the **precautionary principle** and the **polluter pays principles.**
- **Review and Appeal: Powers to review its own decisions**. If this fails, an NGT Order can be challenged before the Supreme Court within 90 days.

Protected Area (PA) has been **defined in the Wildlife (Protection) Act, 1972**. Protected Areas under WPA 1972 include **national parks(NP), wildlife sanctuaries (WLS), conservation reserves (CnRs) and community reserves (CmR)**.

TYPES OF PROTECTED AREAS

Difference between National Park and Wildlife Sanctuary

Feature	National Park	Wildlife Sanctuary
Purpose	Protect ecosystems and biodiversity	Protect specific species and their habitats
Human Activity	Strictly prohibited	Limited activities like grazing may be allowed by the chief wildlife warden
Boundaries	Clearly defined and strictly regulated. Can be altered only on approval by NBWL.	Not always well-defined or strictly regulated. Can be altered only on approval by NBWL. A WLS can be larger than NP in terms of area.
Conversion	National Park can not be converted into a wildlife sanctuary.	Wildlife sanctuary can be converted into a National Park.
Declaration	By State and Central Government both.	By state and Central Government both.
Eco-tourism	Allowed, but strictly regulated (e.g., guided tours, controlled safaris).	Allowed with more flexibility (e.g., eco-lodges, nature walks, cultural tourism).

In addition to National Parks and Wildlife sanctuaries, WPA 1972 also recognises protected areas like community reserves and conservation reserves.

NATIONAL PARKS OF INDIA

There are 106(as of August 2025) existing national parks in India covering an area of 44,402.95 km2, which is 1.35% of the geographical area of the country (National Wildlife Database)

Facts about India's National Parks

- **Largest National Park in India:** Hemis NP (Ladakh) UT of Ladakh
- **Smallest National Park in India:** South Button Island NP Andaman & Nicobar
- **State with largest % of area under National Parks:** Sikkim (25.14%)
- **State with smallest % of area under National Parks:** Telangana (0.02%)
- **Punjab** is the only Indian state that does not have a national park. UTs of Delhi, Puducherry, Chandigarh, Dadra and Nagar Haveli, and Lakshadweep also do not have a national park.

STATE WISE LIST OF KEY NATIONAL PARKS

Andaman & Nicobar Island

1. **Mahatma Gandhi Marine (Wandoor) NP**
   - Located in **South Andaman**.
   - Most of the coral reefs in the park are **fringing reefs**.
2. **Campbell Bay & Galathea Bay NP**
   - **Part of the Great Nicobar BR.**
   - Galathea NP - **southernmost NP of India.**
   - **Vegetation:** Tropical evergreen & semi-evergreen forests.
   - **Major Fauna:** Giant robber crab, megapode, Nicobar pigeon and turtle species (Hawksbill, Olive Ridley, Leatherback, Malayan box and Giant Leatherback).
3. **Mount Manipur (Harriet) NP**
   - **Third-highest peak in the A&N archipelago**, located near Port Blair in **South Andaman**.

- Previously known as Mount Harriet, **renamed** in honour of Manipur's freedom fighters who were imprisoned there.
- **Vegetation:** Tropical evergreen, hilltop tropical evergreen and littoral forests.
- **Major Fauna: Butterfly hotspot.**

4. Rani Jhansi Marine NP

- **Location:** Ritchie's Archipelago, **South Andaman**. It lies in the vicinity of Button Islands.
- **Vegetation:** Mangroves and evergreen forests.
- **Major Terrestrial Fauna:** Spotted deer, water lizards and monitor lizards, **fruit-eating bats**.
- **Major Marine Fauna:** Dugongs, dolphins, sea turtles, blue whales and corals.

5. Saddle Peak NP

- **The highest point of A&N Islands.**
- **Major Fauna:** Andaman wild pig, Andaman imperial pigeon, dolphins, whales and saltwater crocodile

6. Others

- **North Button** Island NP, **Middle Button** Island NP, **South Button** Island NP

Arunachal Pradesh

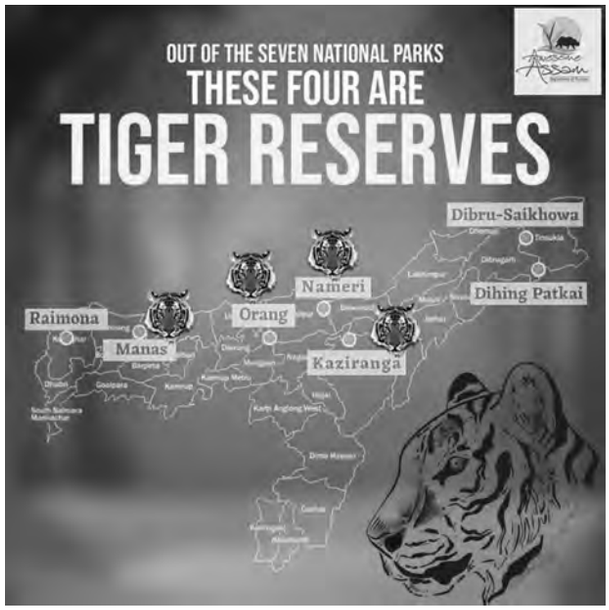
1. Mouling NP

- Named after Mouling Peak. **Mouling NP and Dibang WLS are located within Dihang-Dibang BR**.
- **Vegetation:** Tropical forests (at lower altitudes) to moist temperate forests (at higher altitudes).
- **Fauna:** clouded leopard, takin, red panda, capped langur, macaque, and several bird species.

2. Namdapha NP (also a TR)

- **Location:** Between the **Dapha bum range** of the Mishmi Hills and the Patkai range, crossed by the **Noa Dihing River** which originates at Chaukan Pass, the **largest protected area in the Eastern Himalaya biodiversity hotspot**.
- **Vegetation:** Evergreen to temperate broadleaf forest.
- **It is the only park in the World to have the four Feline species of big cat, namely:** Tiger, Leopard, Snow Leopard and Clouded Leopard.
- It is famous for the **critically endangered Namdapha flying squirrel** which is endemic to the park.
- **Primates:** Stump-tailed macaque, slow loris, Western Hoolock gibbon **(the only 'ape' species found in India)**, capped langur, Assamese macaque and rhesus macaque.

Assam



1. Nameri NP(TR)

- **Location:** Foothills of the Eastern Himalayas & Kameng River flows along its southern boundary. Its northern boundary is shared with the Pakke TR. It has **two core areas: Nameri NP & Sonai-Rupai WLS**.
- **Fauna:** Pygmy Hog, Royal Bengal Tiger, Indian Bison, Asiatic Elephant, Clouded Leopard, Wild Dog, Black Bear, Sambar and hog deer.

2. Raimona NP

- **Location:** Along the Himalayan foothills **together with Buxa TR of West Bengal and Phipsoo WLS and Jigme Singye Wangchuck NP of Bhutan**.
- Bounded by the **Sankosh River** on the west, the **Saralbhanga River** on the east, the Indo-Bhutan border on the north, and Ripu RF on the south.
- **Non-human Primates: Golden langur (EN) (endemic to the region; named as the mascot of Bodoland region)**.
- **Major Avifauna:** White-bellied heron, Oriental darter, lesser adjutant, Bengal florican, hill myna.

3. Orang NP (TR)

- Lies on the **bank of the Brahmaputra River. Pachanoi River, Belsiri River and Dhanshiri River** border the park.It is also known as the mini Kaziranga National Park.
- The park, formed of alluvial flood plains, is an integral part of the **Indo-Burma hotspot of biodiversity**.
- **Vegetation:** Moist deciduous forest, swamp forest, wet alluvial and savannah grassland.

4. Dihing Patkai NP

- **Location:** Foothills of Patkai Hills & Dihing River flows through it.

- Also called **Jeypore Rainforest**, it harbours the largest stretch of lowland rainforests in India.
- **Fauna:** Chinese pangolin, flying fox, wild pig, sambar, barking deer, gaur, serow and Malayan giant squirrels.
- It has the **highest concentration of the White Winged Wood Duck (EN)**

5. Dibru-Saikhowa NP (also a BR)

- Bounded by the **Brahmaputra and Lohit Rivers** in the north and the Dibru River in the south.
- It is **famous for Feral horses**.
- **Vegetation:** Wet evergreen and semi-evergreen, deciduous, littoral and swamp forests.
- **Fauna:** Tiger, Elephant, leopard, jungle cat, bears, small Indian civet, squirrels, Gangetic dolphin, slow loris, Assamese macaque.

6. Kaziranga NP (also a TR)

- Lies in the **Eastern Himalayan biodiversity hotspot** and the **Brahmaputra River** flows through the park.
- Hosting **2/3rd of the world's one-horned rhinoceroses**, it is a World Heritage Site, recognized as an I**mportant Bird Area** by BirdLife International.
- **Major Flora:** Speargrass, **elephant grass**, common reed, cotton tree, and elephant apple.
- **Major Fauna:** One-horned rhinoceros (VU), Royal Bengal Tiger, Asian elephant, wild water buffalo (EN) and swamp deer are collectively known as the '**Big Five' of Kaziranga**.

7. Manas NP (also a TR, ER,BR)

- **UNESCO Natural World Heritage site** located on the Himalayan Foothills, contiguous with the Royal Manas NP (Bhutan). **Manas River** passes through it.
- **Bhabar-terai region** with riverine succession makes it one of the richest areas of biodiversity.
- **Major Avifauna:** It has the **world's largest population of the endangered Bengal florican**. Other major bird species include great hornbills, pelicans, eagles, and herons.

Bihar

1. Valmiki NP (TR, WLS)

- **Location:** Foothill ranges of Siwaliks at the Indo-Nepal border. **River Gandak** forms its western boundary. It is the **only NP in Bihar**.
- **The Harha-Masan River system** originates from the Valmiki NP and forms the Burhi Gandak River down south.
- **Vegetation:** Moist deciduous, semi-evergreen, freshwater swamps, alluvial grasslands, savannah and wetlands.
- **Major Fauna:** Bengal tiger, rhinoceros, Indian flying fox, black bear, sloth bear, leopard, barking deer, spotted deer, hog deer, sambar, clouded Leopard, Indian gaur.
- **'Tharu',** a scheduled tribe, is the dominant community

Chhattisgarh

1. Sanjay (Guru Ghasidas) NP, Sanjay-Dubri TR

- **Location:** Chhattisgarh and Madhya Pradesh, it is **named after Guru Ghasidas of the Satnami sect**. Lies in the Narmada Valley and is a **part of the Sanjay-Dubri TR**.

2. Indravati NP (TR)

- It derives its name from the **Indravati River** that forms its **northern boundary**. It is **home to one of the last remaining populations of the wild water buffalo (EN)**.
- **Major Fauna:** Gaur, blackbuck, chausingha, sambar, chital, Indian muntjac, tigers, pangolins, rhesus monkeys.
- **Major Avifauna:** Common (Bastar) hill myna (LC).
- **Major Reptilian Fauna:** Freshwater crocodile.

3. Kanger Valley NP

- Home to the Bastar **Hill myna (LC)**, It derives its name from the **Kanger River** which flows through it. It has **limestone caves**.
- **Major Reptilian Fauna:** Freshwater crocodile

Goa

1. Mollem NP and Bhagwan Mahaveer Sanctuary

- Located in the Western Ghats in Goa. **National Highway 4A** divides the park into two parts. It is home to waterfalls, such as **Dudhsagar Falls (on the Mandovi River**; it is Goa's tallest waterfall and India's 5th tallest) and **Tambdi Falls**.
- It is known for it's Leopards, Elephants, Deer & Gaur population.
- Home to a community of **nomadic buffalo herders** known as the **Dhangar**.

Gujarat

1. Blackbuck (Velavadar) NP

- It is **bordered by the Gulf of Khambha**t on the south.
- **Vegetation:** Savanna grassland.
- **Major Fauna:** Blackbucks (LC), hyenas, jungle cats.

2. Gir NP and WLS

- Gir NP (Sasan Gir) is near Talala Gir. Today, it is the **only area in Asia where Asiatic lions occur**. Kamleshwar Dam on **Hiran River** is called **'the lifeline of Gir'**.

3. Marine NP (Gulf of Kachchh)

- **Major Fauna:** Corals, sea turtles such as green sea turtles (EN), olive ridleys (VU) and leatherbacks (VU), dugongs (sea cow; VU), Indo-Pacific humpback dolphins.

4. **Vansda (Bansda) NP**
   - Located on the b**anks of the Ambika River** in the Western Ghats.
   - **Major Fauna:** Indian leopard, rhesus macaque, small Indian civet, chausingha, Indian (Malabar) giant squirrel.

Haryana

1. **Kalesar NP**
   - **Location:** Shivalik foothills. It is contiguous to Rajaji NP (Uttarakhand) and Simbalbara NP (Himachal Pradesh). It is bounded by the **Yamuna River** to the east.
2. **Sultanpur NP**
   - It is a **Ramsar Site** located 15 km from Gurugram, the park is famous for **migratory birds**.

Himachal Pradesh

1. **Great Himalayan NP**
   - **Location:** the **Kullu Valley** (formed by Beas River).
   - **It is at the junction of the world's two major biogeographic realms:** the Indomalayan realm to the south and the Palearctic realm to the north.
   - It is a **UNESCO World Heritage Site**.
   - **Vegetation:** Ranges from temperate to subalpine.
   - **Major Flora:** Spruces, horse chestnuts, alpine meadows.
   - **Major Fauna:** Bharal (blue sheep), snow leopard (VU), Himalayan brown bear,
2. **Khirganga NP**
   - It is flanked by the **Great Himalayan NP and Pin Valley NP**.
   - **Vegetation:** Dry alpine and scrub.
3. **Pin Valley NP**
   - **Location:** within the Cold Desert BR in the Himalayan region. Pin River is a tributary of Spiti River
4. **Others**
   - **Inderkilla NP; Simbalbara (Col. Sher Jung) NP**

Jammu & Kashmir

1. **City Forest (Salim Ali) NP**
   - **Major Fauna:** Kashmiri stag (hangul) (CR), musk deer (EN), Himalayan black bear.
   - **Major Avifauna:** Paradise flycatcher, Himalayan monal, and Himalayan snowcock.

Salim Ali (1896-1987): Salim Ali, an Indian ornithologist, was the first Indian to conduct systematic bird surveys across India. He was a key figure behind the Bombay Natural History Society and the creation of the Bharatpur BS (Keoladeo NP).

2. **Dachigam NP**
   - **Location:** Zabarwan Range of Western Himalayas.
   - **Vegetation:** Coniferous forest, alpine pastures, meadows, and scrub vegetation.
3. **Kishtwar NP**
   - Bounded to the north by the Rinnay River, south by the Kibar Nala catchment, east by the main divide of the Great Himalayas, and west by the Marwah River.
   - **Vegetation:** Conifer forests, alpine scrub, and meadows.
   - **Major Fauna:** Snow Leopards, Himalayan snowcock.
4. **Kazinag NP**
   - Kazinag National Park is a national park in Baramulla city of the Baramulla district in the Indian union territory of Jammu and Kashmir notified under Wild Life Protection Act 1972. It is part of a proposal for a trans-Karakoram peace park with Pakistan.

Ladakh

1. **Hemis NP**
   - **Location:** Within the Palearctic realm. It is the **only NP in India that is to the north of the Greater Himalayas**.
   - Bounded on the north by the Indus River, and on the south by the Zanskar Range.
   - It is the **2nd largest contiguous protected area, after the Nanda Devi BR** and is famous for snow leopards. It is the o**nly refuge in India for the Shapu (Ladakhi Urial)**.

Jharkhand

1. **Betla NP**
   - **Location:** Chota Nagpur Plateau. North Koel River (a tributary of Son River) flows through the park.
   - **Betla NP = Palamu TR + Mahuadanr Wolf Sanctuary**
   - **Vegetation:** Bamboo and sal forests.

Karnataka

1. **Anshi NP and Dandeli-Anshi TR (Kali TR)**
   - Located on the banks of Kali River in the Western Ghats. It is a **part of the Dandeli WLS**.
   - Anshi NP and Dandeli WLS were together granted the status of Project Tiger TR and were declared as 'Anshi- Dandeli TR' (which is now renamed as **Kali TR**).
   - **Vegetation:** Deciduous forest & montane rainforest.
   - **Major Flora:** True cinnamon, bamboo, eucalyptus.

- **Major Fauna:** Elephant (EN), Bengal tiger (EN), black panther (a black color variant of leopard; VU), wild boars, bonnet macaque, Malabar civet, Malabar giant squirrel.
- **Major Avifauna:** Adjutant stork, great hornbill.

2. Bandipur NP, TR

- Together with Nagarhole NP, Mudumalai NP (TN) and Wayanad WLS (Kerala), it is **part of the Nilgiri BR**.
- Kabini River **(a tributary of the Cauvery River) s**eparates the park from Nagarhole NP.
- **Vegetation:** Dry & moist deciduous forests, and shrubs.

3. Nagarahole (Rajiv Gandhi) NP, TR

- **Location:** foothills of Western Ghats.
- It is recognized as an **Important Bird Area**.
- **Jenu Kurubas** (honey-collecting tribe) live in this park.
- **Vegetation:** Moist & dry deciduous forests, swamp forests, and bamboo

4. Bannerghatta NP

- It is **part of a wildlife corridor for elephants** which connects Biligirirangana Hills and Sathyamangalam forest.
- **Vegetation:** Moist deciduous forest and scrubland.
- A portion of the NP is converted into Bannerghatta Biological Park.

5. Kudremukh NP

- Located in the **Western Ghats**
- The park is named after the **Kudremukh Peak**, which is the third-highest peak in Karnataka and is characterized by its distinctive horse-shaped outline **("Kudremukh" translates to "horse face" in the local language)**.

Andhra Pradesh

1. Papikonda NP

- **Location: Papi Hills of Eastern Ghats.** It is an **Important Bird and Biodiversity Area.**
- **Major Fauna:** Bengal tiger, leopard, hyena, Indian gaur, sloth bear, spotted deer (chital), sambar, barking deer(or Indian muntjac), four-horned antelope (chausingha), kanchu mekha (an endemic dwarf goat).
- **Major Avifauna:** Common peacock, red jungle fowl.
- **Major Reptiles:** Indian golden gecko, monitor lizard.
- The NP has a **population of both Rhesus macaque** (normally found north of Godavari) **and Bonnet macaque** (usually found south of Godavari).

2. Rajiv Gandhi (Rameswaram) NP

- **Location:** Rameswaram of Kadapa district. It lies on the north bank of the Penna
- **Major Avifauna:** Little egrets, parakeets.
- **Major Amphibian Fauna:** Bullfrog.
- **Major Reptilian Fauna:** Burrowing snakes (Russell, earth boa, John and boa).

3. Sri Venkateswara NP

- **Location:** Part of the **Seshachalam Hills BR**. It spreads over the Seshachalam Hills and the Tirumala Hills of Eastern Ghats.
- **Major Flora:** Red Sanders.
- **Major Fauna:** Slender loris, leopard, sloth bear, mouse deer, Chausingha, Indian giant squirrel.

Kerala

1. Anamudi Shola NP

- **Location:** Western Ghats, Anamudi (2695 m)
- Surrounded by **Mathikettan Shola NP, Eravikulam NP, Pambadum Shola NP, Chinnar WLS**, and the Kurinjimala WLS. (All are part of Munnar Wildlife Division).
- **Major Fauna:** Lion-tailed macaques, Nilgiri tahr (EN), Nilgiri marten (VU), gaur, muntjac, giant grizzled squirrel (NT), flying squirrels, Nilgiri langur (VU).

Sholas

- Tropical montane forests in the Western Ghats, separated by rolling grasslands in high altitudes.
- House a dense patch of stunted trees with the presence of lichen, mosses, and climbers.
- NOTE: Lichens are pollution-sensitive organisms and serve as bioindicators of air quality; their absence often indicates polluted environments. (RAS 2023)

2. Periyar NP(TR, ER)

- It forms the **major watershed of two important rivers of Kerala, the Periyar and the Pamba**. It is located in the Cardamom Hills of the Western Ghats.
- It **surrounds the Periyar Lake** which became a reservoir in 1895 after the **Mullaperiyar Dam** (built at the confluence of the Mullayar and Periyar rivers in Kerala but is operated and maintained by Tamil Nadu) **was erected**.

3. Silent Valley NP

- Silent Valley NP is located in the **Nilgiri Hills** in the Malappuram district, Kerala, and Nilgiris district of Tamil Nadu. The park lies within the Nilgiri BR
- **Bhavani River** (a tributary of the Kaveri River) and **Kunthipuzha River** (a tributary of Bharathapuzha River) originate in the vicinity of the park. The **Kadalundi River** also originates in this park.

4. **Others: Eravikulam NP, Mathikettan Shola NP, Pambadum Shola NP**

Madhya Pradesh

1. **Bandhavgarh NP (TR)**
   - **Location:** At **Vindhya Range. India's first white tiger** was captured here in 1951. The density of the tiger population at Bandhavgarh is one of the highest in India.
   - **Vegetation:** Moist and mixed deciduous forests.
   - **Major Fauna:** Bengal tiger, elephant, leopard, sambar, barking deer, Indian wolf, striped hyena, nilgai.
   - **Major Avifauna:** Indian grey hornbill, lesser adjutant stork, lesser spotted eagle, Bonelli's eagle.
   - The **Indian bison was reintroduced from Kanha**.
2. **Dinosaur (Ashmadha) Fossils NP**
   - **Location: Narmada Valley.**
   - Dinosaur egg fossils and fossilized trees dating back 60 million years were discovered at the site.
3. **Indira Priyadarshini Pench NP, TR**
   - **Location: Satpura Range. Pench River** flows through the park dividing it into two halves.
   - Pench TR straddles across Madhya Pradesh and Maharashtra. It comprises the Indira Priyadarshini Pench NP (MP) and the Jawahar Nehru Pench NP (Maharashtra).
   - **Collarwali ('The One With a Collar')**, the first tigress in the park fitted with a radio collar recently died.
   - Pench NP was the inspiration for **Rudyard Kipling's 'The Jungle Book'**.
4. **Kanha NP, TR**
   - **Location:** Maikal Range of Satpuras. It is the largest NP of Madhya Pradesh and Central India.
   - The present-day Kanha area is divided into two protected areas, **Hallon and Banjar**.
   - **Tribes displaced from the region:** The **Baiga tribe** (a semi-nomadic tribe of Central India) lost their forest rights & were not properly compensated.
5. **Madhav NP**
   - **Sakhya Sagar and Madhav Sagar** are two important reservoirs within the park built by Madho Rao Scindia. Sakhya Sagar has been designated as a Ramsar site since 2022.
   - **Vegetation:** Dry deciduous forests and grasslands.
   - **Major Fauna:** Chinkara (Indian gazelle), chital, nilgai, sambar, chausingha (four-horned antelope).
6. **Mandla Plant Fossil NP**
   - **Location:** Narmada Valley. It has **plant fossils** that existed in India between 40-150 million years ago.
7. **Panna NP, TR**
   - Panna NP along with Ken Gharial WLS, form a significant part of the **catchment area of the Ken River** which runs through the park.
   - In the Ken WLS, **gharials** (fish-eating freshwater crocodiles) are bred in captivity and then released.
   - **Vegetation:** Fragmented deciduous forests.
   - **Major Fauna:** Tiger, leopard, chital, chinkara, sambar.
   - In 2012, no tigers were left in the reserve. A tiger each from Bandhavgarh NP and Kanha NP were translocated to Panna TR
8. **Kuno NP**
   - Located in Vindhyan hills in the Sheopur district.
   - It derives its name from the Kuno River that flows through the national park.
   - **Flora:** The park's diverse ecosystems include dry deciduous forests, grasslands, and riverine habitats.
   - **Fauna:** Bengal tigers, leopards, Indian wolves, sloth bears, and various ungulates like chital, sambar, and nilgai.In September 2022, Kuno became the site for the reintroduction of cheetahs in India, with eight individuals translocated from Namibia.
9. **Sanjay NP, Sanjay-Dubri TR**
   - It is already covered under Chhattisgarh.
10. **Satpura NP, TR**
    - It was **India's first reserve forest**, located in the Satpura Range. It has the Dhoopgarh peak (1,350 m) and the level plains of Churna.
    - **Pachmarhi** is the closest city to the park.
11. **Van Vihar NP**
    - It is located in **Bhopal**. It has the status of an NP but is **developed and managed as a zoological park**.
    - **Captive Fauna:** Bengal tiger, Asiatic lion, mugger crocodile, gharial, spotted deer (chital), sambar, blackbuck

Maharashtra

1. **Gugamal NP (Melghat TR)**
   - **Location:** Amravati region. **Tapi River and Gawilgarh Hills** (of Satpura Range) form its northern boundary.
   - **Gugamal NP is part of Melghat TR**. It is one of seven protected areas in the Melghat TR.
   - **The TR is a catchment of five major rivers:** Khandu, Khapra, Sipna, Gadga and Dolar (all tributaries of Tapti).

2. Nawegaon NP

- Dr Salim Ali Bird Sanctuary, Navegaon is home to almost 60% of bird species found in the entire Maharashtra.
- **Navegaon Nagzira TR = Nawegaon NP + Nagzira WLS + Koka WLS**.

3. Jawaharlal Nehru Pench NP, TR

- Spread across Madhya Pradesh and Maharashtra. It comprises the Indira Priyadarshini Pench NP (MP) and the Jawahar Nehru Pench NP (Maharashtra).
- **Major Fauna:** Royal Bengal tiger, leopard, sloth bear, gaur, four-horned antelope.

4. Chandoli NP (Sahyadri TR, Koyna WLS)

- Sahyadri TR = Chandoli NP + Koyna WLS.
- **Location:** Sahyadri Range of the Western Ghats.
- Koyna WLS has two reservoirs along the Koyna River, Shivsagar Lake and Koyna Reservoir.

5. Sanjay Gandhi (Borivilli) NP

- **Location:** Mumbai. 2400-year-old Kanheri caves sculpted out of a massive basalt lie within the park. It served the Buddhist centers of education.

6. Tadoba NP (Tadoba Andhari TR, Andheri WLS)

- **Maharashtra's oldest and largest NP. Tadoba Lake and Erai Reservoir** are the major wetlands in the reserve. Erai Reservoir offers a good habitat for mugger crocodiles (marsh crocodiles).
- **Tadoba Andhari TR = Tadoba NP + Andhari WLS**
- **Vegetation:** Dry deciduous forest.
- **Major Flora:** Teak, tendu.
- **Major Fauna:** Tigers, leopards, sloth bears, Indian wild dogs, and herbivores like gaur and deer. It also shelters over 195 bird species, including crested serpent eagles and paradise flycatchers, along with reptiles like pythons and marsh crocodiles.

Manipur

1. Keibul-Lamjao NP

- **Only floating park in the world**. It is an **integral part of Loktak Lake (a Ramsar site)**.
- Characterized by floating decomposed plant materials locally called **phumdis**.
- Declared a NP to preserve the natural refuge of brow-antlered deer (also called **sangai**, dancing deer & Manipurs's Eld's deer).

2. Shirui National Park:

- **Famous for Shirui Lily**,The local name of the flower is **Kashong Timrawon**.

Meghalaya

1. Balphakram NP

- **Location:** Garo Hills in Meghalaya, close to the Indo-Bangladesh border.
- **Major Fauna:** Barking deer, Asian golden cat, tiger, marbled cat, wild water buffalo, red panda, elephant.

2. Nokrek Ridge NP

- **Location:** close to Tura Peak in West Garo Hills. It forms the core area of the Nokrek BR.
- **Important Bird Area**. All important rivers of the Garo Hills region rise from the Nokrek Range, of which the **Simsang River** (known as Someshwari in Bangladesh) is most prominent.
- **Vegetation:** Evergreen, semi-evergreen and deciduous.
- **Major Fauna:** Red panda, Asian elephant, stump-tailed macaque, pig-tailed macaque, hoolock gibbon.

Mizoram

1. Murlen NP

- **Location:** Close to the Chin Hills of Myanmar. It is to the south of Lengteng WLS.
- **Vegetation:** Semi-evergreen and sub-montane forests.
- **Major Fauna:** Tiger, leopard, Malayan giant squirrel, Himalayan black bear, serow, hoolock gibbon.
- **Major Avifauna:** Mrs. Hume's pheasant (NT), the state bird of Mizoram and hill myna

2. Phawngpui Blue Mountain NP

- It covers the entire **Phawngpui Mountain or Blue Mountain** (2,157 m), the highest peak of Mizoram.
- **Major Fauna:** Slow loris, tiger, leopard, serow, goral.
- Mrs. Hume's pheasant (NT), the state bird of Mizoram

Nagaland

1. Ntanki National Park (Intanki National Park)

Odisha

1. Bhitarkanika NP (Ramsar Site)

- It is the **second RS of Odisha** after Chilika Lake. **Gahirmatha Marine Sanctuary separates the NP from the Bay of Bengal**. It is inundated by the rivers **Brahmani, Baitarani & Dhamra**.
- It hosts many mangrove species and is the **second-largest mangrove ecosystem in India**.
- **Major Fauna:** Saltwater (Estuarine) Crocodile (LC).

2. Simlipal NP(TR,BR)

- **Location:** Eastern Ghats and is listed in the UNESCO World Network of BRs.

- **Mayurbhanj ER** = Similipal TR + Hadgarh + Kuldiha WLS.
- **Vegetation:** moist and dry deciduous forests, and grasslands.
- **Major Fauna:** Bengal tigers, wild elephants, gaurs (Indian bison), chausingha.

Rajasthan

1. Desert NP

- **Location:** It is spread over two districts. It is one of the natural habitats of the Great Indian Bustard
- **Vegetation:** Open grassland, thorny bushes, and dunes.
- **Major Flora:** Patches of sewan grass and aak shrub.
- **Major Avifauna:** Great Indian bustard (CR), eagles, harriers, falcons, buzzards, and vultures.
- **Major Fauna:** Chinkara or Indian Gazelle, desert fox

2. Mukundra Hills NP (TR)

- Previously known as **Darrah WLS**, located within the **Kathiawar-Gir dry deciduous forests ecoregion**.
- Like Sita Mata WLS, Mukundara Hills NP was one of the places that were considered for the reintroduction of the Asiatic lion.
- **Major Fauna:** Bengal tiger, Indian wolf, leopard, chital, sambar, wild boar, sloth bear and chinkara, Mugger crocodile and gharial.

3. Keoladeo Ghana NP (RS)

- Formerly known as **Bharatpur BS**, it is a **freshwater swamp**. It gets flooded during the monsoon.
- A famous **avifauna sanctuary** that hosts thousands of birds, especially during the winter season. It is a **Ramsar Site** and a **UNESCO World Heritage Site**.
- It is the **only regular wintering** area in India for the Siberian crane (CR).
- **Major Avifauna:** Migratory waterfowl, sarus crane (large non-migratory crane found in parts of India).
- **Major Fauna:** Blackbuck, hog deer, chital deer, sambar.

4. Ranthambore NP, TR

- It is bounded to the north by the **Banas River** and to the south by the **Chambal River**.
- **Major Fauna:** Bengal Tiger, leopard, nilgai, sambar, Mugger crocodile.

5. Sariska NP, TR

- Part of the Aravalli Range and the Kathiawar-Gir dry deciduous forests ecoregion. It is **rich in mineral resources**, such as copper.
- **Vegetation:** Arid forests, dry deciduous forests, scrub-thorn and grasslands.
- **Major Fauna:** Bengal tiger, Indian leopard, golden jackal, chital, sambar deer, nilgai, rhesus macaque.

Sikkim

1. Khangchendzonga NP (BR)

- The park gets its name from the mountain **Kanchenjunga, the third-highest peak in the world**.
- It is the first and only **"Mixed Heritage" site in India**. It is also included in the **UNESCO Man and the Biosphere Programme**.
- **Vegetation:** Temperate broadleaf and mixed forests.
- **Fauna:** snow leopard, red panda, Himalayan blue sheep, serow, goral, takin

Tamil Nadu

1. Annamalai (Indira Gandhi) NP (TR, WLS)

- **Location:** in the **Anaimalai Hills**.
- **Vegetation:** Wet evergreen forest to shola grassland.
- **Major Fauna:** Bengal tiger, Indian elephant, Indian leopard, Nilgiri tahr, lion-tailed macaque, gaur, Nilgiri langur.
- **Threats:** Tea and coffee plantations and tourism.

2. Guindy NP

- **Guindy Snake Park** and **IIT Madras** are located at the periphery of Guindy NP. The Madras Crocodile Bank Trust is only 30 km away from Guindy NP.
- **Vegetation:** Tropical dry evergreen forest, dry evergreen scrub, and thorn forest.
- **Major Fauna:** Blackbucks (flagship species of the park), chital, jackals, etc.

3. Gulf of Mannar Marine NP

- Consists of 21 small islands (islets) and adjacent coral reefs. It is the **core area of the Gulf of Mannar BR**.
- Includes marine components such as coral reefs, seaweed, seagrasses, salt marshes, and mangroves.
- **Major Marine Fauna:** Dugong (Sea Cow), Green turtles, Olive Ridley turtles. Dugong (VU), a marine mammal, is the flagship mammal of the park.

4. Mudumalai NP, TR, WLS

- **Location:** north-western side of the Nilgiri Hills (Blue Mountains), in Nilgiri district. It shares its boundaries with the states of Karnataka and Kerala.
- **Vegetation:** Tropical moist deciduous, dry deciduous, and dry thorn forests.
- **Major Fauna:** Indian elephant, Bengal tiger, leopard, bonnet macaque, sloth bear, Indian giant

squirrel, Indian white-rumped vulture (CR) and India Vulture (CR).

5. **Mukurthi NP**
   - **Location: Within Nilgiri BR**. The NP was created to protect its keystone species, the **Nilgiri tahr (EN)**.
   - **Vegetation:** Montane grasslands and shrublands interspersed with sholas.

Telangana

1. **Kasu Brahmananda Reddy National Park (KBR Park)**
   - **Location:** Located in Hyderabad,
   - **Flora and Fauna:** This urban park is known for its greenery and biodiversity, including peacocks, butterflies, and various bird species.
2. **Mahavir Harina Vanasthali National Park**
   - Situated near Hyderabad, it is named after Lord Mahavir.
   - **Fauna:** It is known for its population of blackbucks and other wildlife.
3. **Mrugavani National Park**
   - Located near Chilkur in Hyderabad,
   - **Fauna:** this park is home to various mammals like Spotted Deer (Chital),Indian Hare,wild boar,porcupine,junglecat

Tripura

1. **Bison (Rajbari) NP**
   - NP in the **Trishna WLS**, established to restore the natural living habitat of **India Bison**.
   - **Gumti River** originating from the Gumti WLS (in Tripura), separates the Sipahijala WLS (Clouded Leopard NP) from Trishna WLS (Bison NP).
   - **Rudrasagar Lake** (RS) is located between the Sipahijala WLS and the Trishna WLS.
2. **Clouded Leopard NP**
   - **Part of the Sipahijala WLS**. Sipahijala WLS is a **woodland with an artificial lake** and natural botanical and zoological gardens.
   - Sipahijala WLS is famous for **clouded leopards (VU)**.

Uttarakhand

1. **Gangotri NP**
   - **Location:** Upper catchment of Bhagirathi River.
   - The park area forms a **continuity between Govind NP and Kedarnath WLS**. The **Gaumukh glacier**, the origin of the river Ganges is located inside the park.
   - **Habitat:** Coniferous forests, alpine meadows, and glaciers.
   - **Vegetation:** Pine, deodar, fir, and rhododendrons.
   - **Major Fauna:** Snow leopard, Asian black bear, brown bear, musk deer, blue sheep, Himalayan tahr.
2. **Govind Pashu Vihar NP and WLS**
   - The **Snow Leopard Project** is being managed at this sanctuary.
   - **Vegetation:** Himalayan broadleaf forests, conifer forests, alpine shrubs, and meadows.
   - **Flora:** Pine, Deodar, cedar, oak, maple, walnut, horse chestnut, hazel and rhododendron.
   - **Major Fauna:** Snow Leopard (VU), leopard, musk deer, Himalayan tahr, steppe eagle, bearded vulture.
3. **Jim Corbett NP, Corbett TR**
   - **Oldest NP in India (1936)** and is located in **Nainital**.
   - The park was the **first NP to come under the Project Tiger initiative**.
   - Corbett TR's core area is formed by Jim Corbett NP, while the buffer contains Sonanadi WLS.
   - **Ramganga, Sonanadi, and Kosi** are the major rivers flowing through the NP, and Ramganga Reservoir is located within the NP.
   - **Vegetation:** Dense, moist deciduous forests, marshy depressions, and grasslands.
   - **Major Fauna:** Bengal tigers, elephants, leopards, Himalayan black bears, Himalayan goral, rhesus macaque. Local crocodiles and gharials were saved from extinction by captive breeding programs that subsequently released crocodiles into the Ramganga River.
   - **Threats:** Invasive weeds, and poaching.
   - Corbett NP is **one of the thirteen protected areas covered by the Worldwide Fund For Nature** under their Terai Arc Landscape Program.
4. **Rajaji NP, TR**
   - **Location:** Spreads over the Shivalik ranges and the Indo-Gangetic plains. The Ganga and Son Rivers flow through the park.
   - The park is at the north-western limit of distribution for both elephants and tigers in India.
   - **Major Fauna:** Elephants, Bengal tiger, sloth bear, black bear, Indian langur, Indian porcupine.
5. **Nanda Devi BR, NP**
   - India's second BR and it is **under UNESCO's Man & Biosphere Programme**. Its core area is **formed by Nanda Devi NP and Valley of Flowers NP**.
   - The Nanda Devi NP is situated around the peak of Nanda Devi (7816 m). It is a **UNESCO World Heritage Site**.
6. **Valley of Flowers NP**
   - It is a high-altitude Himalayan valley in the **transition zone between Zanskar and Great Himalayas**.

- It is known for its meadows of endemic alpine flowers. NPs lies completely in the **Temperate alpine zone**
- Both the Valley of Flowers NP and the Nanda Devi NP form the **core area of Nanda Devi BR**.

West Bengal

1. **Buxa NP, TR**
   - Lies in the **Gangetic Plains**. Its northern boundary runs along the Indo-Bhutan border.
   - **Vegetation:** Evergreen and semi-evergreen, moist and dry deciduous, savannah and grasslands.
   - **Major Fauna:** Bengal tiger, Asian elephant, gaur, sambar deer, clouded leopard, Indian leopard.
2. **Gorumara NP**
   - **Location:** in the Eastern Himalayas Terai belt. The major river of the park is the **Jaldhaka River**, a tributary of the Brahmaputra.
   - **Vegetation:** Rolling forests and riverine grasslands known as Duars and moist deciduous forests.
   - **Major Fauna: Indian rhinoceros,** gaur, **Asian elephant**, sloth bear, chital, sambar deer, barking deer, hog deer.
3. **Jaldapara NP**
   - **Location:** banks of the Torsa River at the foothills of the Eastern Himalayas.
   - **Largest population of the Indian one-horned rhinoceros after Kaziranga NP** in Assam.
   - It is located near Chilapata Forests which is an elephant corridor between **Jaldapara and Buxa** TR while Gorumara NP is known for its population of Indian rhinoceros.
   - **Vegetation:** Mainly savannah with tall elephant grasses.
   - **Major Fauna:** Indian rhinoceros, leopards, elephants, sambar, barking deer, spotted deer, hog deer, gaur.
4. **Neora Valley NP**
   - **Location:** Himalayas in Kalimpong.
   - **Vegetation:** Himalayan broadleaf forests.
   - **Major Flora:** Rhododendron, bamboo, oak, ferns, sal.
   - **Major Fauna:** Red Panda, Indian leopard, black bear, sloth bear, golden cat, barking deer, Himalayan flying squirrel, thar.
5. **Singalila NP**
   - **Location:** Singalila Ridge in Darjeeling.
   - **Vegetation:** Coniferous, broadleaf, and mixed forests.
   - **Major Fauna:** Red panda, yellow-throated marten, pangolin, Himalayan black bear, clouded leopard, takin.
6. **Sunderban NP(TR, Ramsar Site ,BR)**
   - **Largest delta and mangrove forest in the world**. Sundarbans NP is a part of the Sundarbans on the Ganges Delta and is adjacent to the Sundarban Reserve Forest in Bangladesh. Bound on the west by river Muriganga and on the east by rivers Haribhanga and Raimangal.
   - It is also a B**R, TR, Ramsar Site and a UNESCO World Heritage Site**.
   - Eco-geography of this area is dependent on the tidal effect. The tidal action deposits silt back on the channels, raising the bed and forming new islands and creeks.
   - **Vegetation:** Mangrove forests (Sundarbans has achieved its name from the Sundari mangrove tree).
   - **Major Fauna:** Royal Bengal Tiger, saltwater crocodile, river terrapin, olive ridley turtle, Ganges River dolphin, hawksbill turtle, mangrove horseshoe crab.

WILD LIFE SANCTUARIES OF INDIA

There are 573(as of March 2025) existing wildlife sanctuaries in India covering an area of 123,762.56 km2, which is 3.76% of the geographical area of the country (National Wildlife Database).

Andaman & Nicobar Islands

1. **Barren Island WLS:** Barren Island is the **only active volcano in India**.
2. **Narcondam Island WLS:** Narcondam Island is a **dormant volcano**.

Andhra Pradesh

1. **Coringa WLS:** It is a part of the Godavari estuary (delta), Mangroves, and dry deciduous tropical vegetation with Fauna Including estuarine crocodile (saltwater crocodile; LC).
2. **Gundla Brahmeswaram WLS:** Located on the periphery of Nagarjunasagar-Srisailam TR in the Nallamala Hills.
3. **Kolleru WLS (BS):** Natural eutrophic lake situated between the river basins of the Godavari and the Krishna.
4. **Krishna WLS: mangrove wetland located in the Krishna delta.**
5. **Pulicat Lake WLS (BS):** Located in Andhra Pradesh and Tamil Nadu, India's second largest brackish-water ecosystem after Chilka Lake in Odisha.
6. **Rollapadu WLS (BS):** Established to protect Great Indian Bustard (CR) and Lesser Florican (EN).
7. **Sri Lankamalleswara WLS: Located in the southern** part of the **Nallamala Hills**. The WLS is known for **Jerdon's courser bird (CR)**.

8. **Sri Penusila Narasimha WLS:** It comprises a unique forest type viz. the **dry evergreen forests**. Such vegetation is unique to the Coromandel Coast (Tamil Nadu, Puducherry and Andhra Pradesh)

Arunachal Pradesh

- **Kamlang TR, WLS:** Named after the **Kamlang River**, which flows through it. It is located between the **Lohit River & Namdapha NP**.
- **Dibang WLS:** It is located **within Dihang-Dibang BR**.

Assam

1. **Chakrasila WLS:** North bank of the Brahmaputra River, an Important protected habitat for golden langur (EN) after Manas NP.
2. **Deepor Beel WLS (Ramsar Site): Permanent freshwater lake** in a former channel of the Brahmaputra River.
3. **Hollongapar Gibbon WLS:** Contains **India's only apes – the hoolock gibbons (EN)**, and North-eastern India's only nocturnal primate – the Bengal slow loris (VU).
4. **Pobitora WLS:** Pobitora (Mini Kaziranga) has exceeded its rhino-bearing capacity. Under the **Indian Rhino Vision 2020 (IRV 2020)** several rhinos were translocated from Pobitora and re-introduced into the Manas NP.
5. **Barnadi WLS** (established to protect the Hispid hare (EN) and Pygmy hog (EN) on Himalayan foothills bordering Bhutan);
6. **Burachapari WLS** (south bank of the Brahmaputra River, habitat for the Bengal florican (CR));
7. **Garampani WLS**
8. **Lawkhowa WLS** (between Kaziranga NP and Orang NP, ideal habitat for Indian rhinoceros (VU) and Asiatic water buffaloes (EN));
9. **Marat Longri WLS** (important component of Dhansiri-Lungding ER);
10. **Nambor WLS** (on the periphery of the Mikir Hills)
11. **Nambor-Doigrung WLS** (along with Garampani WLS, Nambor WLS is a part of the Kaziranga-Karbi Anglong ER);
12. **Pani-Dihing WLS** (BS)
13. **Sonai Rupai WLS** (west of Pakke TR and Nameri NP);
14. **Amchang WLS, Barail WLS, East Karbi Anglong WLS**.

Bihar

1. **Kaimur WLS:** Eastern part of the Vindhyan Scrap Lands. It is Bihar's largest WLS and is a tiger corridor
2. **Kanwar Jheel WLS (BS) (Ramsar Site):** Asia's **largest freshwater oxbow lake**.
3. **Vikramshila Gangetic Dolphin WLS:** Protected area for **India's national aquatic animal – Gangetic Dolphins (EN)**.
4. **Barela Jheel Salim Ali Bird WLS**
5. **Kusheshwar Asthan Bird WLS** (Close to the right bank of River Kosi (Sorrow of Bihar) and Kanwar Lake);

Chattisgarh

1. **Badalkhol WLS:** Located in Ramgarh Hills, It is a tiger corridor between Achanakmar TR (Chhattisgarh) & Palamau TR (Jharkhand).
2. **Bhairamgarh WLS:** Indravati River (a tributary of Godavari) separates Indravati NP from Bhairamgarh WLS.
3. **Bhoramdev WLS:** Tiger corridor in Maikal Hills between Kanha TR (Madhya Pradesh) and Achanakmar TR (Chhattisgarh).
4. **Others: Pamed Wild Buffalo WLS; ; Sarangarh-Gomardha WLS; Barnawapara WLS**

Goa

1. **Dr. Salim Ali Bird (Chorao) WLS:** Estuarine mangrove habitat located on Chorao Island along the Mandovi River.
2. **Mhadei WLS (IBA):** Mhadei River passes through the Mhadei WLS and meets the sea at Panaji

Gujarat

1. **Barda WLS:** It was a p**revious range of Asiatic lions**.
2. **Gaga (Great Indian Bustard) WLS:** Established to protect Great Indian Bustard (CR). Along with Kutch Bustard Sanctuary, Gaga WLS is one of two great Indian bustard sanctuaries in Gujarat.
3. **Girnar WLS:** In Girnar Hills; famous for Asiatic lions (EN).
4. **Jessore Sloth Bear WLS:** At Gujarat-Rajasthan border for the protection of sloth bear (VU). The Banas River separates Jessore Sloth Bear WLS from Balaram Ambaji WLS.
5. **Kutch (Lala-Parjan) Great Indian Bustard WLS:** Established to protect the Great Indian Bustard (CR) (locally called Ghorad).
6. **Kutch Desert WLS:** It is a **shallow seasonal saline wetland** in the Great Rann of Kutch. Fossils of dinosaurs, crocodiles, and whales have been recovered from here.
7. **Nal Sarovar Bird WLS (BS) (Ramsar Site): Natural freshwater lake** (a relict sea) located in the Thar Desert. It is the largest wetland BS in Gujarat. **Lifeline for the Indian Wild Ass (NT) & blackbuck (LC)**.
8. **Narayan Sarovar Chinkara WLS:** Its flagship species is Chinkara (LC).
9. **Shoolpaneswar (Dhumkhal) WLS:** Common boundary with Madhya Pradesh and Maharashtra. Tapti River separates Shoolpaneswar WLS from Purna WLS.

10. **Thol Lake WLS** (man-made reservoir) , **Wild Ass WLS** (one of the last places where Indian wild ass (NT) can be spotted), **Khijadiya Bird WLS (BS), Mitiyala WLS**

Himachal Pradesh

1. **Dhauladhar WLS Location:** In the Lesser Himalayas, it lies between Dalhousie (near Ravi River) and Kullu-Manali Valley (Beas River). Ravi River flows along the fringes of the Dhauladhar range. Hanuman Tibba (5,982 m) is its highest peak.
2. **Pong Dam Lake WLS (BS) (Ramsar Site):** Also called **Maharana Pratap Sagar**, it was created on the Beas River. Pong Dam and Gobindsagar Reservoir (on the Sutlej River) are the two most important fishing reservoirs in the Himalayan foothills of Himachal Pradesh.

Jammu & Kashmir

1. **Gulmarg WLS: Located on the** foothills of Pir Panjal Range.
2. **Hokersar/ Hokera WLS (Ramsar Site):** Natural perennial wetland contiguous to the Jhelum basin. It is an important migratory bird area.
3. **Tral WLS:** Created to conserve **hangul (Kashmir Stag; CR**) and acts as **a buffer around Dachigam NP and Overa-Aru WLS**.
4. **Rajparian (Daksum) WLS:** It is disturbed due to excessive grazing by **nomadic Bakarwals**. The Bakarwal are nomads of the Pir Panjal and Himalayan mountains. They are **transhumants**.

Ladakh

1. **Changthang WLS (Ramsar Site):** It has one of the highest lakes on earth, **Tso Moriri** (4595 m).
2. **Karakoram (Nubra Shyok) WLS: Location:** High-altitude WLS located in the easternmost reaches of the Karakoram range. It is one of the few places with a migratory population of the chiru/Tibetan antelope (NT).

Jharkhand

1. **Mahuadar Wolf WLS:** Located along the Jharkhand-Chhattisgarh border. It is a breeding ground for Indian Wolf.
2. **Palkot WLS:** Located in contiguous with the Koel River Valley forests, Saranda-Singhbhum Range forests, and Dalma WLS.
3. **Dalma WLS:** It is an important elephant corridor in the Dalma Hills.
4. **Gautam Budha WLS:** It covers the Lower Gangetic Plains (moist deciduous forests) and Chota Nagpur (dry deciduous forests).
5. Parasnath WLS (in Parasnath Hills (Chota Nagpur Plateau));
6. Udhwa Lake Bird Sanctuary (only BS of Jharkhand state);

Karnataka

1. **Bhimgad WLS:** Located in the Western Ghats and is the only known **breeding area of Wroughton's free-tailed bat** (CR). It is contiguous to Madei WLS (Goa), Bhagwan Mahaveer WLS Mollem NP (Goa), and Dandeli WLS (Karnataka).
2. **Brahmagiri WLS:** Western Ghats and is contiguous with the Aralam WLS of Kerala.
3. **Cauvery WLS:** Contiguous with BR Hill TR (Karnataka), Sathyamangalam TR (TN), and Dharmapuri forest (TN).**Hogenakal Falls and Mekedatu** are important locations of the WLS.
4. **Ranganathittu WLS (BS)/ Pakshi Kashi of Karnataka: Largest BS in the state**, It receives thousands of migratory birds from Siberia, Latin America, and parts of north India during winter.
5. **Ramadevara Betta WLS (Vulture Sanctuary): India's first vulture sanctuary**.
6. Talakaveri WLS (source of the river Kaveri, located on Brahmagiri hills).
7. Kamasandra WLS (located at trijunction of Karnataka, Andhra Pradesh & Tamil Nadu)

Kerala

1. **Chinnar WLS:** Integral part of the protected forests straddling the Kerala-Tamil Nadu border in the Anaimalai Hills. The **rare Albino gaur** (Manjampatti white bison) is found only in Indira Gandhi WLS and Chinnar WLS.
2. **Idukki WLS:** It is cradled by the **Cheruthoni River and Periyar River**. Cardamom Hills lies between Mathikettan NP and Idukki WLS.
3. **Malabar WLS:** Part of Nilgiri BR and Wayanad ER.
4. **Kurinjimala WLS:** Protects the **core habitat of the endangered Neelakurinji plant (blossom only once in 12 years)**. The WLS is contiguous to the Chinnar WLS, Eravikulam NP, Anamudi NP, Pampadum Shola NP, and the proposed Palani Hills NP.
5. **Neyyar WLS:** It is the drainage basin of **Neyyar River and Neyyar Dam**. It is a **part of the Agasthyamala BR**.
6. **Peechi-Vazhani WLS:** It consists of **Palappilli-Nelliyampathi forests**, including the area of Chimmony WLS.
7. **Wayanad WLS: Integral part of the Nilgiri BR**. It is bounded by **Nagarhole NP, Bandipur NP** (Karnataka) and **Mudumalai NP**. It is a major elephant and tiger corridor.

Madhya Pradesh

1. **Bori WLS:** Located in the foothills of the **Satpura Range**. It is bounded by Satpura NP and Tawa River (tributary of Narmada). The sanctuary, **together with Satpura NP and Pachmarhi WLS, forms Pachmarhi BR**.

2. **Ken Gharial WLS:** Panna NP along with Ken Gharial WLS form a significant part of the catchment area of the Ken River (a tributary of Yamuna). In the Ken Gharial WLS, **fish-eating freshwater crocodiles (CR) are bred in captivity and then released**.
3. **National Chambal Gharial WLS:** Located on the Chambal River near the tripoint of Rajasthan, Madhya Pradesh, and Uttar Pradesh. It is a **tri-state protected area** for the Gharial (CR), red-crowned roof turtle (CR), and Ganges river dolphin (flagship species; EN). It is listed as an Important Bird Area.
4. **Noradehi WLS:** It is the **largest WLS of Madhya Pradesh**, spread over the southern area of the **Vindhya Range** in which Bandhavgarh NP and Panna NP are also located.
5. **Pachmarhi WLS: Pachmarhi BR is situated in the Satpura Range. It includes three wildlife conservation units:** Bori WLS, Pachmarhi WLS & Satpura NP.
6. **Kuno WLS:** Cheetahs from Namibia were released here as part of cheetah reintroduction in India.
7. **Panna (Gangau) WLS** (Panna TR = Panna NP + Gangau WLS + Ken Gharial WLS);
8. **Panpatha WLS** (Bandhavgarh TR = Bandhavgarh NP + Panpatha WLS);
9. **Sailana or Kharmour WLS** (BS) (home to the 'Kharmour' bird, a very rare species);
10. **Son Gharial WLS** (natural habitat of Gharial and marsh crocodile.

Maharashtra

1. **Great Indian Bustard WLS:** Also known as **Jawaharlal Nehru Bustard Sanctuary**. The land is **drought-prone and semi-arid**.
2. **Koyna WLS:** Important Bird Area located in the Western Ghats. Sahyadri TR **lies between Koyna WLS and Chandoli NP**.
3. **Lonar WLS (Ramsar Site):** It is a saline-alkaline lake located in Buldhana district. It is a 56,000-year-old crater created by a meteor impact during the Pleistocene Epoch (2.58 million to 11,700 years ago).
4. **Nandur Madhameshwar WLS (BS) (Ramsar Site):** It is located in Nashik at the confluence of the Godavari and Kadwa Rivers. It is Maharashtra's first Ramsar site.
5. Amba Barwa WLS (Melghat TR = Gugamal NP + Melghat WLS, Narnala WLS & Amba Barwa WLS);
6. Bhimashankar WLS (habitat of Indian (Malabar) Giant Squirrel (LC), the state animal of Maharashtra);
7. Chaprala WLS (Pranhita River flows along its western boundary, serves as a link between the Tadoba TR (Maharashtra) and the Indravati TR (Chhattisgarh));

Haryana

1. Morni Hills (Khol-Hi-Raitan) WLS & Bir Shikargarh WLS; Chhilchhila Lake WLS (Seonthi Reserve Forest); Khaparwas WLS (BS)

Manipur

1. Bunning WLS; Khongjaingamba Ching; Thinungei BS (first BS of Manipur); Yangoupokpi Lokchao (along the Indo-Myanmar border); Zeilad WLS

Meghalaya

1. Narpuh WLS (Jaintia Hills); Nongkhyllem WLS; Siju Bird WLS(banks of Simsang River)

Mizoram

1. Khawnglung WLS (Lushai Hills); Lengteng WLS (Lushai Hills); Ngengpui WLS (Mizo Hills); Tawi WLS (Lushai Hills); Thorangtlang WLS; Tokalo WLS

Nagaland

1. Fakim WLS (Naga Hills); Puliebadze WLS; Rangapahar WLS

Odisha

1. **Gahirmatha Marine WLS:** World's largest nesting beach for Olive Ridley Sea Turtles (VU). Dhamra River mouth in the north to Brahmani River mouth in the south.
2. **Chilika Lake RS & Nalbana BS:** Chilika Lake is a brackish water lagoon. It is a shallow bar-built estuary fringed by the Eastern Ghats. It is located at the mouth of the Daya River. It is the largest coastal lagoon in India and the largest brackish water lagoon in Asia. In 1981, Chilika Lake was designated India's first Ramsar Site. The Irrawaddy dolphin (EN) is the flagship species of Chilika Lake. Chilika is home to the only known population of Irrawaddy dolphins in India. Chilika is the largest wintering ground for migratory birds on the Indian subcontinent. Birds from as far as the Caspian Sea, Lake Baikal, and Aral Sea come here.
3. **Nalbana BS:** Core area of Ramsar wetlands of Chilika Lake. It hosts thousands of migratory birds. The island disappears during monsoon due to inundation, only to emerge again in post-monsoon.
4. Lakhari Valley WLS (Rushikulya River flows through the region;
5. Nandankanan WLS (captive breeding of Asiatic lions, tigers and crocodiles);
6. Satkosia Gorge WLS (Saktosia TR = Satkosia Gorge WLS + Baisipalli WLS);

Punjab

1. **Abohar WLS:** Located close to the intersection of Haryana, Rajasthan & Punjab. It spreads over the private land inhabited by the Bishnoi community.
2. **Harike Lake WLS (Ramsar Site):** Large wetland formed after constructing the headworks across the Sutlej river.

3. **Nangal WLS (Ramsar Site):** Located on Shivalik foothills. It occupies a human-made reservoir constructed as part of the Bhakra-Nangal Project. Here, Indian and Chinese Prime Ministers formalized the 'Five Principles of Peaceful Coexistence' in 1954.

Rajasthan

1. **Bhensrodgarh WLS; Mukundara Hills (Darrah) WLS (consists of three wildlife sanctuaries:** Darrah WLS, Chambal WLS, and Jawahar Sagar WLS);
2. Jaisamand WLS; Jamwa Ramgarh WLS (man-made lake);
3. Jawahar Sagar WLS; Kailadevi WLS (extension of the Ranthambore NP);
4. Mount Abu WLS (located in the Aravalli range);
5. National Chambal WLS (located on the Chambal River near the tripoint of Rajasthan, Madhya Pradesh, and Uttar Pradesh);
6. Ramgarh Vishdhari WLS;
7. Sawaimadhopur WLS (part of Ranthambore TR);
8. Sawai Man Singh WLS (part of Ranthambore TR);

Telangana

1. **Eturnagaram WLS:** Part of the Dandakaranya forests. The Godavari River passes through the sanctuary. It is inhabited by the Koya Tribes. The biennial Sammakka Saralamma Jatara (Medaram Jatara) is held in the WLS.
2. **Others:** Kinnerasani WLS; Lanja Madugu Siwaram WLS (right bank of the Godavari River); Manjeera Crocodile WLS; Pranahita WLS (located on the bank of Pranahita River); Pakhal WLS; Pocharam WLS.

Tripura

1. Sepahijala WLS (Clouded Leopard NP is located here);
2. Trishna WLS (Bison/Rajbari NP is located in the Trishna WLS);
3. Gumti WLS; Rowa WLS.

Tamil Nadu

1. **Cauvery North WLS:** Forms the vital link to the Male Mahadeshwara Hills (Karnataka), Biligiri Ranganathaswamy Hills (Karnataka), Sathyamangalam WLS (Tamil Nadu) and Nilgiri BR.
2. Cauvery South WLS (Grizzled giant squirrel, four-horned antelope, and lesser fish eagle are exclusively dependent on the Cauvery river and its riverine forest ecosystem);
3. Kadavur Slender Loris WLS (India's first slender loris sanctuary);
4. Megamalai WLS (buffer to Periyar TR and Srivilliputhur Grizzled Squirrel WLS);
5. Koonthankulam-Kudankulam WLS (IBA);
6. Melaselvanoor-Keelaselvanoor WLS (BS);

Uttar Pradesh

1. **Bakhira WLS:** Natural floodplain wetland, The Rapti River flows through it. It provides a wintering ground for a number of migratory birds.
2. **Jai Prakash Narayan (Surhatal) Bird WLS:** Near the confluence of Ghaghara and Ganges Rivers.
3. **Katerniaghat WLS:** It provides connectivity between the tiger habitats of Dudhwa NP (Uttar Pradesh) and Bardia NP (Nepal).
4. **Kishanpur WLS:** The Sarda River (known as Kali River before it reaches the plains; it flows along the Indo-Nepal Border) separates Kishanpur WLS from the Dudhwa NP.
5. National Chambal Gharial WLS (tripoint of Rajasthan, Madhya Pradesh, and Uttar Pradesh);
6. Nawabganj Bird WLS (Ramsar Site) (also known as Shahid Chandra Shekhar Azad BS);
7. Parvati Aranga WLS (Ramsar Site) (ox-bow lake formed by the Ghaghara River);
8. Saman Bird WLS (Ramsar Site) (seasonal oxbow lake on the Ganges floodplain);
9. Sandi Birds WLS (Ramsar Site, freshwater marsh designated as an Important Bird Area by BirdLife International);
10. Shekha Bird WLS (perennial lake);
11. Sur Sarovar Bird WLS (right bank of Yamuna River);

Uttarakhand

1. **Kedarnath WLS:** It has been set up for conserving the musk deer (EN). It stretches from Gaurikund to Kedarnath mountain. Mandakini River flows through the WLS.
2. **Askot WLS:** set up for conserving the musk deer (EN).
3. **Nandhaur WLS:** Jim Corbett TR lies between Rajaji TR and Nandhaur WLS. Nandhaur WLS is a part of the Shivalik ER.

West Bengal

1. **Chapramari WLS:** It is contiguous with Gorumara NP. They lie between Teesta and Jaldhaka Rivers.
2. **Mahananda WLS:** It is located on the foothills of the Himalayas in the Darjeeling district, between the Teesta and Mahananda Rivers (a small tributary of Ganga).
3. **Others:** Lothian Island WLS; Raiganj Bird WLS; Sajnakhali WLS; Senchal WLS; West Sunderban WLS (Part of larger Sundarbans region).

Chandigarh

1. **City Bird WLS: It is also known as Parrot BS as it is primarily a habitat of parrots.**
2. **Sukhna Lake WLS**

Puducherry

1. **Oussudu WLS (BS) (spreads in Puducherry and Tamil Nadu)**

Lakshadweep

1. **Pitti (Bird Island) WLS (uninhabited coral islet in Lakshadweep)**

TIGER RESERVES

- In 1973, with an aim to protect tigers from extinction, India launched Project Tiger in Jim Corbett National Park of Uttarakhand. A network of tiger reserves was gradually established based on a core-buffer strategy.
- All the tiger reserves are governed by the **Project Tiger (1973),** a Centrally Sponsored Scheme of MoEFCC, and administered by the National Tiger Conservation Authority. {Jim Corbett National Park (1936), originally called Hailey National Park, is the first national park established in India.(RAS 2016)}

NTCA (National Tiger Conservation Authority)

- The National Tiger Conservation Authority (NTCA) is a statutory body under the Ministry of Environment, Forest and Climate Change. **It was established in 2005 under the Wildlife Protection Act, 1972** to oversees the implementation of Project Tiger.
- No alteration in the boundaries of a tiger reserve shall be made except on a recommendation of the NTCA and the approval of the NBWL(National Board for Wild Life)
- No State Government cannot de-notify a tiger reserve, except in public interest with the approval of the NTCA and National Board for Wild Life.

Core- Buffer Strategy for Tiger Reserves

- In this strategy, the whole tiger reserve area is divided into core forest and buffer forest. As per this strategy, the central part of the forest was marked as core forest.
  - It is a critical tiger habitat thus put in the core forest category, making it undisturbed from human intervention.

OUTER WORLD
BUFFER FOREST
CORE FOREST
(No hotel, no village, only patrol camps, critical tiger habitat)
Mixed land with villages & hotels
Outside tiger reserve

Distinction Between Critical Tiger Habitat (CTH) and Critical Wildlife Habitat (CWH)

Feature	Critical Tiger Habitat (CTH)	Critical Wildlife Habitat (CWH)
Definition	Areas within tiger reserves crucial for tiger conservation under the Wildlife Protection Act, 1972.	Areas in protected areas identified for wildlife conservation under the Forest Rights Act, 2006.
Legal Framework	Governed by the Wildlife Protection Act, 1972.	Governed by the Forest Rights Act, 2006.
Rights of Communities	Requires settlement or relocation of forest-dwelling communities without affecting their rights.	Rights can only be modified or curtailed with informed **consent of Gram Sabha** and after due process.
Authority Responsible	National Tiger Conservation Authority **(NTCA).**	Ministry of Environment, Forest, and Climate Change **(MoEFCC)**.

TIGER RESERVES IN INDIA (58)

India is home to over 70% of the world's tiger population and boasts of 58 dedicated protected areas dedicated to the conservation of tigers. Madhav National Park becomes India's 58th tiger reserve.

- **Largest Tiger Reserves in India (by Core Area):** Nagarjunsagar Srisailam TR (Andhra Pradesh)
- **Largest Tiger Reserves in India (by Total Area):** Nagarjunsagar Srisailam TR (Andhra Pradesh)
- **Smallest TR in India:** The Bor Tiger Reserve in Maharashtra.
- The Jim Corbett National Park in Uttarakhand has the highest tiger density in India.

Map shows 54 Tiger reserves of India. Newer Tiger reserves of Dholpur–Karauli@(2023), Guru Ghasidas–Tamor Pingla (2023) and Ratapani@(2024) are not given in the image.

Andhra Pradesh

1. **Nagarjunasagar Srisailam TR:**
   - **Largest TR in India.** It spreads over **Andhra Pradesh and Telangana.**
   - It is located inside the **Nallamala Hills & the Krishna River** cuts through the reserve. **Srisailam Reservoir and Nagarjuna Sagar Reservoir** lie within the reserve.
   - **Largest area Under "Critical Tiger Habitat".**

Arunachal Pradesh

1. **Kamlang and Namdapha TR : Already Covered in National Park Section**
2. **Pakke (Pakhui) TR:**
   - Lies in the **foothills of the Eastern Himalayas.** It is bounded by the **Kameng River** in the west and north and by the **Pakke River** in the east. To the south, the sanctuary adjoins Assam's Nameri NP and to the west, it is bounded by Eaglenest WLS and Sessa Orchid Sanctuary.
   - It is known for its **Hornbill Nest Adoption Programme**

Assam

1. **Manas TR, Orang TR, Nameri TR, Kaziranga** TR-details of these have been covered above under National Parks.

Bihar

1. **Valmiki TR**

Chhattisgarh

1. **Indravati TR, Achanakmar TR, Udanti-Sitanadi TR: It comprises Sitanadi WLS and Udanti WLS.**
2. **Guru Ghasidas Tamor Pingla TR**
   - Adopting a landscape approach it ensures ecological connectivity with neighbouring tiger reserves like Sanjay Dubri (Madhya Pradesh), Bandhavgarh (Madhya Pradesh), and Palamau (Jharkhand).

Jharkhand

1. **Palamu TR**
   - It is **one of the nine original TRs in India.**
   - It forms part **of Betla NP and Palamu WLS. The North Koel River runs** through it.

Karnataka

Name	Features
Bandipur TR	It is part of the Nilgiri Biosphere Reserve and is renowned for its Bengal tiger population, Asian elephants, leopards, and diverse flora and fauna.
Nagarahole TR (Rajiv Gandhi)	It is located in the foothills of Western Ghats. It is recognized as an Important Bird Area.
Biligiri Rangana-tha Temple TR	It is the starting point of Eastern Ghats. The Biligiri Ranganatha Hills (BR Hills) connect the Eastern Ghats and Western Ghats and facilitate gene flow between populations of species in these areas. Major fauna over here includes -Wild elephants, tiger, gaur, sambhar, chital.
Dandeli-Anshi TR	Anshi National Park and Dandeli Wildlife Sanctuary were together granted the status of Project Tiger Tiger Reserve, and were declared as 'Anshi-Dandeli Tiger Reserve' (which is now renamed as Kali Tiger Reserve).
Bhadra TR	Lies to the east of Kudremukh National Park. It is surrounded by scenic hills, including the Baba Budangiri hills. Tiger, leopard, Malabar civets, **Malabar giant squirrel,** spotted deer, bonnet macaque, **lion-tailed macaque (EN)** etc are the main fauna found here.

Kerala

- **Periyar TR**
  - The Periyar Tiger Reserve in Kerala is the best-maintained of all tiger reserves in the country, according to the 5th cycle of Management Effectiveness Evaluation (MEE). It is located in the western ghats, and is traversed by the Periyar and Pamba rivers. The fauna includes Elephants, Wild Pigs, Sambar, Gaur, Mouse Deer, Dole or Barking Deer, Indian Wild Dog and Tiger.
- **Parambikulam TR**
  - **Location:** Sungam range of hills between Anaimalai Hills (TN) and Nelliampathy Hills (Kerala).
  - **Vegetation:** Evergreen, moist deciduous, and sholas.
  - **Major Fauna:** Lion-tailed macaques, Nilgiri tahr, Nilgiri langurs, Nilgiri marten, small Travancore flying squirrel.

Madhya Pradesh

1. **Bandhavgarh TR, Kanha TR, Panna TR, Pench TR, Sanjay-Dubri TR ,Satpura TR**
   - Already covered under National Parks.
2. **Damoh Tiger Reserve:** The central government has issued a notification approving the proposal to merge the Noradehi Sanctuary with the Rani Durgavati Sanctuary of the Damoh district, creating a vast tiger reserve spanning 2,300 square kilometres.

3. **Ratapani TR (added in Dec 2024) and 4. Madhav National Park (added in 2025)**

Maharashtra

1. **Melghat TR, Navegaon-Nagzira TR, Pench TR, Sahyadri TR, Tadoba-Andhari TR**
2. **Bor TR/ WLS**
   - It includes the drainage basin of the Bor Dam.
   - **Vegetation:** Dry deciduous forests.
   - **Major Fauna:** Bengal tiger, Indian leopard, Indian bison, blue bull, chital, barking deer, mouse deer.

Mizoram

1. **Dampa TR**
   - It is located in the **Lushai Hills (Mizo Hills).**
   - Though no tiger was found in the reserve in the 2022 tiger census.
   - It has **one of the highest clouded leopard (VU)** populations in South & South East Asia.

Rajasthan

1. **Mukundra Hills TR, Ranthambore TR, Sariska TR**
2. **Ramgarh Vishdhari TR**
   - It acts as a **buffer for Ranthambore NP.**
   - It will link **Ranthambore TR & Mukundra Hills TR**.
   - The government is making efforts to strengthen the prey base by transferring chital (spotted deer) from Ghana BS (Karauli) to Mukundra Hills TR, Keoladeo NP, and Ramgarh Vishdhari TR.
3. **Dholpur-Karauli TR**
   - Rajasthan's 5th and India's 55th tiger reserve, approved in August 2023.
   - The reserve encompasses diverse habitats that support a variety of wildlife, including tigers, leopards, hyenas, and multiple deer species.

Odisha

1. **Simlipal TR**
   - It is part of the Eastern Ghats and features dense forests, grasslands, and stunning waterfalls like Barehipani and Joranda.
   - It is **home to a significant population of Bengal tigers, along with leopards, elephants, gaurs, and various deer species.**
   - It **also hosts a wide variety of bird species, reptiles, and endemic flora. It is also a UNESCO-recognized Biosphere Reserve**
2. **Satkosia TR**
   - It encompasses Satkosia Gorge WLS and the Baisipalli WLS.
   - The TR is located where the **Mahanadi River** passes through a long gorge in the Eastern Ghats.
   - The area is also a **part of the Mahanadi ER.**

Tamil Nadu

Name	Features
Anamalai TR **Mudumalai TR**	❖ Features discussed above under National Parks
Sathyamangalam TR, WLS	❖ It is located in the **Eastern Ghats.** ❖ Sathyamangalam TR = **Sathyamangalam + Hasanur Forest Divisions.** ❖ It is a wildlife corridor in the Nilgiris BR between the Western Ghats and the Eastern Ghats and a **genetic link between BR Hills WLS, Mudumalai NP and Bandipur NP.**
Kalakad-Mundanthurai TR	❖ It forms **part of the Agasthyamalai BR.** ❖ Agasthyamalai Hill Range is the **core zone of the TR.** ❖ **Major Fauna:** Tiger, leopard, elephant, gaur, sambar, chital, Nilgiri tahr, mouse deer, lion-tailed macaque.
Srivilliputhur-Megamalai TR	❖ Created by **combining Srivilliputhur Grizzled Giant Squirrel Sanctuary and Megamalai WLS.** ❖ Biggest beneficiary is the dying **Vaigai River** (that drains to the Palk Strait). The formation of TR has kept the rivers perennial in the region. ❖ It is a **part of the Brahmagiri-Nilgiris-Eastern Ghats ER.**

Telangana

1. **Kawal TR**
   - The **Godavari River** flows along its southern boundary.
   - **Major Fauna:** Tiger, leopard, gaur, cheetah, sambar, nilgai, barking deer, Chausingha, sloth bear
2. **Amrabad TR, WLS**
   - **Earlier, part of Nagarjunasagar-Srisailam TR,** but post-bifurcation, the northern part of the reserve

is vested with Telangana state and renamed as Amrabad TR.

- It is **India's second-largest TR,** next only to Nagarjunasagar Srisailam TR.
- **Chenchu tribe:** It is a hunter-gatherer community, designated as a Scheduled Tribe in Andhra Pradesh, Telangana, Karnataka, and Odisha.

Uttar Pradesh

1. **Amangarh TR**
   - It forms an **extension of and buffer to Jim Corbett NP.**
   - After the state of Uttarakhand was carved out of Uttar Pradesh, Jim Corbett went to Uttarakhand and Amangarh remained in Uttar Pradesh.
2. **Dudhwa TR, NP**
   - It is located in the **Terai belt (Indo-Nepal border).**
   - **Dudhwa TR = Dudhwa NP + Kishanpur WLS + Katarniaghat WLS.**
   - The **Sharda River** (Kali or Mahakali River) separates Dudhwa NP from Kishanpur WLS. The **Ghaghara River** separates Dudhwa NP from Katarniaghat WLS. Indian rhinoceros (VU) was **reintroduced** into Dudhwa from Pobitora Sanctuary (Assam). Black-crested bulbul (LC) was spotted after several years.
3. **Pilibhit TR**
   - It lies in the **Terai belt (on the Indo-Nepal border).** Sharda Sagar Dam is on the east and **River Sharda** (a tributary of River Ghaghara) is on the northeast.
4. **Ranipur TR, WLS**
   - It is 54th TR in India.
   - Ranipur WLS has no tigers of its own, but it is frequented by tigers from the nearby Panna TR. Ranipur WLS is an **important corridor for the movement of tigers.**

Uttarakhand

1. **Jim Corbett TR, Rajaji TR**

West Bengal

1. **Buxa TR, Sunderbans TR**

ELEPHANT RESERVES OF INDIA

- India has the **largest number of wild Asian elephants** in the world, estimated at 29,964 according to the **2017 census,** about 55% of the species' global population.
- They range in 33 Elephant Reserves spread over 10 elephant landscapes in 14 states, covering about 80,000 sq km of forests across India.
- The 'home range' of an elephant herd can vary from an average of about 250 sq km (in Rajaji NP) to over 3500 sq km (in the highly fragmented landscapes of West Bengal).

East-Central Landscape (WB – Jharkhand –Orissa)	❖ Mayurjharna ER – West Bengal, Odisha ❖ Singhbhum ER – Jharkhand (comprises of Dalma WLS) ❖ Mahanadi ER – Odisha (Satkosia TR = Satkoshia Gorge WLS + Baisipalli WLS) ❖ Sambalpur ER – Odisha ❖ Baitami (Brahmani-Baitarani) ER– Odisha ❖ South Orissa ER – Odisha ❖ Lemru ER – Chhattisgarh ❖ Badalkhol-Tamorpingla Elephant Reserve – Chhattisgarh (constitutes Badalkhol WLS and forests between Badalkhol WLS and Guru Ghasidas NP.)
Kameng-Sonitpur Landscape (Arunachal – Assam)	❖ **Kameng Elephant Reserve – Arunachal Pradesh** ❖ Sonitpur Elephant Reserve – Assam & Arunachal Pradesh (southern extension of Kameng ER, The Nameri TR, and Sonai Rupai WLS are a part of this reserve)
Eastern-South Bank Landscape (Assam – Arunachal)	❖ Dihing-Patkai ER – Assam (Dihing Patkai NP is a part of Dehing Patkai ER) ❖ South Arunachal Elephant Reserve – Arunachal Pradesh (Namdapha TR is a part of this ER.
Kaziranga-Karbi Anglong-Intanki Landscape	❖ Kaziranga-Karbi Anglong ER – Assam (Kaziranga TR, Nambor-Doigrung WLS, Garampani WLS, Nambor WLS are a part of this ER) ❖ Dhansiri-Lungding ER – Assam ❖ **Intanki ER – Nagaland** ❖ Singphan ER – Nagaland
North Bengal-Greater Manas Landscape	❖ Chirang-Ripu ER – Assam (part of the buffer zone of Manas TR. These forests have the largest known population of the endangered Golden Langur (EN)) ❖ Eastern Dooars ER – West Bengal
Meghalaya Landscape	❖ Garo Hills ER – Meghalaya (consists of Nokrek NP, Balpakram NP and Siju WLS and the surrounding Reserved Forests) ❖ Khasi Hills ER – Meghalaya

Brahmagiri-Nilgiri-Eastern Ghat Landscape	❖ Mysore ER – Karnataka (integral part of Muttodi (Bhadra TR) – Brahmagiri – Nagarholle TR – Bandipur TR Corridor, Nagarhole TR and Bandipur TR are a part of the Nilgiri BR) ❖ Wayanad ER – Kerala (Wayanad WLS and Aralam WLS are a part of the Nilgiri BR) ❖ Nilgiri ER – Tamil Nadu (consists of the entire Nilgiri BR of Tamil Nadu) ❖ Rayala ER – Andhra Pradesh ❖ Nilambur ER – Kerala (Salient Valley NP, New Amarambalam WLS are a part of this ER ❖ Coimbatore ER – Tamil Nadu
Annamalai-Nelliyam-pathy Land-scape (TN – Kerala)	❖ Anamudi ER and Anamalai ER are separated from Nilgiris by Palakkad Gap. ❖ Anamalai ER – Tamil Nadu, Kerela
Peri-yar-Agasthya-malai Land-scape (Kerala – Tamil Nadu)	❖ Periyar ER – Kerala (Periyar NP and WLS was declared as an Periyar ER) ❖ Srivilliputhur ER ❖ Agasthyamalai ER (Agasthyamalai ER is also a BR. It includes Shendurney WLS, Peppara WLS, Neyyar WLS, and Kalakkad Mundanthurai TR)
North-Western Landscape (Uttarakhand – Uttar Pradesh)	❖ Shivalik ER – Uttarakhand (It constitutes Jim Corbett TR, Rajaji TR, Sonanadi WLS, DehraDun forests and other Shivalik forest divisions sprawling in Garhwal and Kumaon hills) ❖ Uttar Pradesh ER – Uttar Pradesh ❖ Terai ER – Uttar Pradesh (include Dudhwa TR, Pilibhit TR and areas of Kishanpur and Katarniaghat WLS)

Ramsar Sites

Ramsar Sites are wetlands designated as internationally important under the Ramsar Convention 1971, an international convention for the conservation and sustainable use of wetlands. Their conservation is based on the 'wise-use' principle.

- **The Cobourg Peninsula in Australia was the world's first Ramsar site, identified in 1974.**
- **The United Kingdom has the most Ramsar sites in the world with 176.**
- **Bolivia has the largest area with 148,000 square km under the Convention protection.**

Newly Designated Ramsar Sites in India (2025)

- **Nanjarayan Bird Sanctuary:** Tamil Nadu
- **The Kazhuveli Bird Sanctuary:** Tamil Nadu
- **The Tawa Reservoir:** Madhya Pradesh

Ramsar Sites of India (96- by Dec 2025)

- **State with highest no. of sites:** Tamil Nadu

Andhra Pradesh (1)	**Kolleru** Lake
Assam (1)	**Deepor** Beel
Bihar (6)	**Kanwar** (Kabar) Taal, Nagi Bird Sanctuary, Nakti Bird Sanctuary, Gokul Jalashay, Udaipur Jheel and Gogabeel Lake
Goa (1)	Nanda Lake
Gujrat (5)	Khijadia WLS; Nalsarovar BS; **Thol** Lake; and Wadhvana Wetland, Chhari-Dhand.
Haryana (2)	Bhindawas WLS and Sultanpur NP
Himachal Pradesh (3)	Chandra Taal; **Pong Dam Lake; and Renuka Lake**
Jharkhand(1)	**Udhwa Lake**
Karnataka (4)	Aghanashini Estuary, Ankasamudra Bird Conservation Reserve, Mgadi Kere Conservation reserve, Ranganathituu BS
Kerala (3)	Ashtamudi Wetland; Sasthamkotta Lake and Vembanad-Kol Wetland (Longest Lake in India)
Madhya Pradesh (5)	Bhoj Wetland; Sakhya Sagar; Sirpur wetland; and Yashwant Sagar, Tawa Reservoir
Maharashtra (3)	Lonar Lake (Impact Crater Lake); Nandur Madhameshwar and Thane Creek (Flamingo Sanctuary)
Manipur (1)	Loktak Lake
Mizoram (1)	Pala Wetland
Odisha (6)	Chilika Lake; Ansupa Lake; Bhitarkanika Mangroves; Hirakud Reservoir; Satkosia Gorge and Tampara Lake.
Punjab (6)	Beas CnR; Harike Wetland; Kanjli Wetland; Keshopur-Miani CmR; Nangal WLS and Ropar Wetland
Rajasthan (5)	Keoladeo National Park , Sambhar Lake, Khichan Wetland, Siliserh Lake and Menar Wetland Complex
Sikkim (1)	Khechopalri Wetland

Tamil Nadu (20-maximum)	Chitrangudi BS; Gulf of Mannar Marine BR; Kanjirankulam BS; Karaivetti BS; Karikili BS; Kazhhuvelli BS; Koonthankulam BS; longwood Shola RF; Nanjaryan BS; Pallikaranai Marsh Reserve Forest; Pichavaram Mangrove; Point Calimere WLS & BS; Suchindram Theroor Wetland Complex; Udhayamarthandapuram BS; Vaduvur BS; Vedanthangal BS; Vellode BS and Vembannur Wetland Complex Sakkarakottai Bird Sanctuary and Therthangal Bird Sanctuary.
Tripura (1)	Rudrasagar Lake
UT of JK (5)	Hokera Wetland **;** Hygam Wetland CnR; Shallbugh Wetland CnR; Surinsar-Mansar Lakes and Wular Lake
UT of Ladakh (2)	Tso Kar (High Altitude Ramsar Site) and Tsomoriri (High Altitude Ramsar Site)
Uttar Pradesh (13)	Bakhira WLS; Haiderpur Wetland; Nawabganj BS; Parvati Arga BS; Saman BS; Samaspur BS; Sandi BS; Sarsai Nawar Jheel; Sur Sarovar (Keetham Lake) and Upper Ganga River (Brijghat to Narora) , Shekha Lake Bird Sanctuary (Aligarh district) and Patna Bird Sanctuary (Etah district), Jai Prakash Narayan Bird Sanctuary
Uttarakhand (1)	Asan Barrage
West Bengal (2)	East Kolkata Wetlands and Sundarban Wetland (Largest Ramsar Site in India)
Chhatisgarh(1)	Kopra Jalashay

Largest, Smallest and Oldest Ramsar Sites in India

	Ramsar site	State	Area(km2)
Largest	**Sundarban Wetland**	West Bengal	4230
Smallest	**Renuka Lake** **Vembannur Wetland Complex**	HP TN	0.2 0.2
Oldest	**Chilika** **Keoladeo Ghana**	Odisha Rajasthan	1981 1981

BIOSPHERE RESERVES

- A Biosphere Reserve is a designated area that promotes the balanced relationship between humans and nature by integrating conservation, sustainable use of natural resources, and scientific research.
- It is based on the principle of zonation and is divided into the following three zones as follows:

Features	Core Zone	Buffer Zone	Transition Zone
Definition	Central, strictly protected area of a biosphere reserve.	Surrounds the core zone, and serves as a buffer for activities compatible with conservation.	Outer zone where sustainable human activities are promoted.
Primary Function	Conservation of biodiversity and ecosystems.	Research, education, and limited activities that support conservation.	Development, sustainable resource use, and community engagement.
Human Activity	Prohibited or minimal (e.g., scientific monitoring).	Regulated activities like tourism, research, and education.	Extensive human activity, including agriculture, settlements, and industries.

- Biosphere reserves are sites established by countries and recognized under UNESCO's Man and the Biosphere (MAB) Programme to promote sustainable development based on local community efforts and sound science.
- The World Network of Biosphere Reserves currently consists of 738 sites in 134 countries, including 22 transboundary sites.
- Spain has the most biosphere reserves (BRs) in the world, with 53 properties

Biosphere Reserves of India

Presently, there are **18 notified biosphere reserves in India (13 of them are recognized by UNESCO's MAB)**

Cold Desert, Himachal Pradesh	❖ It includes **Pin Valley National Park, Chandratal, Sarchu and Kibber** Wildlife Sanctuaries. ❖ Major Fauna: Snow Leopard (VU), Himalayan Ibex (also referred to as Siberian Ibex – LC).
Nanda Devi, Uttrakhand (UNESCO's MAB)	❖ **Nanda Devi NP + Valley of Flowers NP.** ❖ Major Fauna: Snow Leopard (VU), Musk Deer (EN), Bharal Or Blue Sheep (LC), etc.
Khangchendzog, Sikkim (UNESCO's MAB)	❖ **Transboundary biodiversity hotspot** conservation area. It includes the **third-highest mountain peak in the world, Kanchenjunga** (8,586 m). ❖ The **Khangchendzonga NP, which comprises the core area of the KBR,** was inscribed as **India's first "Mixed World Heritage Site".** ❖ **Major Fauna:** Red Panda (EN), Snow Leopard (VU), Musk Deer (EN), Great Tibetan Sheep(Argali) etc.
Dehang-Debang, Arunachal Pradesh	❖ The **Mouling NP and the Dibang WLS** are located fully or partly within this biosphere reserve. The terrain is rugged, with an altitudinal range of 750 to 3000 m at the highest point, the **Mouling Peak.** ❖ **Major Fauna:** Takin (VU), Red Panda (EN).
Manas, Assam	❖ Manas BR = **Manas National Park.** It is contiguous with the **Royal Manas National Park** in Bhutan. Manas is famous for its population of the Wild Water Buffalo (EN). ❖ **Rare and Endemic Wildlife:** Assam Roofed Turtle (EN), Hispid Hare (EN), Golden Langur (EN) and Pygmy Hog (EN). ❖ **The Grassland Biomes Inhabits:** Pygmy Hog, Rhinoceros (re-introduced in 2007), elephants, Bengal florican (CR), etc.

Dibru-Saikhowa, Assam	❖ Dibru-Saikhowa BR = **Dibru-Saikhowa National Park.** ❖ **Major Fauna:** Bengal Tiger, Clouded Leopard (VU), Gangetic Dolphin (EN), etc.
Nokrek, Meghalaya (UNESCO's MAB)	Nokrek (1,412 m) is the highest peak of the Garo hills. **Vegetation:** Evergreen, semi-evergreen & deciduous. **Key Fauna:** Red Panda (EN), Hoolock Gibbons (EN), Red Giant Flying Squirrel (LC), etc.
Panna, Madhya Pradesh (UNESCO's MAB)	❖ Panna Biosphere Reserve = **Panna TR.** ❖ **Fauna:** Tiger (EN), Chital (LC), Chinkara (LC), Sambar (VU). ❖ Latest Site to be add in **UNESCO's MAB**
Pachmarhi, Madhya Pradesh (UNESCO's MAB)	❖ Pachmarhi BR **(Satpura NP + Bori WLS + Pachmarhi WLS)** lies in the centre of the Satpura Range. The highest peak is the **Dhoopgarh** (1,352 m). **Gonds** are the major tribes.
Achanakmar-Amarkantak, Madhya Pradesh, Chhattisgarh (UNESCO's MAB)	❖ It extends across the states of **Madhya Pradesh and Chhattisgarh. Maikal hills** together with eastern **Vindhyas** and **Satpuras** lie within the reserve. ❖ **Major Fauna:** Four Horned Antelope (Chausingha (VU)), Indian Wild Dog (EN), etc. ❖ **Vegetation:** moist deciduous and dry deciduous forests.
Kachchh, Gujarat (Largest Area)	❖ The Great Rann of Kutch is a salt marsh in the Thar Desert. ❖ Great Rann of Kutch BR = **Kachchh Desert Sanctuary (in Great Rann of Kutch) + Wild Ass Sanctuary (in Little Rann of Kutch), Narayan Sarovar Sanctuary + Kutch Bustard Sanctuary + Banni Grasslands Reserve.** ❖ Major Fauna: Great Indian Bustard (CR), Indian Wild Ass (NT), etc.
Similipal, Odisha (UNESCO's MAB)	❖ It includes the **Mayurbhanj Elephant Reserve (Similipal TR + Hadgarh WLS + Kuldiha WLS).** ❖ **Tribes: Erenga, Kharias, Mankirdias, Ho, Gonda & Munda.** ❖ **Major Fauna:** Royal Bengal Tigers, Wild Elephants (EN), Gaurs (VU – Indian Bison), Chausingha (VU).
Sundarban, West Bengal (UNESCO's MAB)	❖ Located in the vast Delta of the Ganges, south of Kolkata and **bordering Bangladesh in the east.** It provides habitat for the threatened Royal Bengal Tiger (EN). ❖ Sundarbans BR = **Sundarbans NP + Sajnekhali WLS + Lothian WLS + Haliday WLS.**
Seshachalam, Andhra Pradesh	❖ The Seshachalam Hills are part of the **Eastern Ghats** (south of the **Panna River**) in southern Andhra Pradesh. ❖ **Tirupati,** a major Hindu pilgrimage town, and **Sri Venkateswara NP** are located in these ranges. ❖ **Major Flora:** rare and endemic plant species like Red Sanders (NT) are of great economic importance. ❖ **Major Reptilian Fauna:** Golden Gecko (LC – Endemic To Tirumala Hills).
Agasthyamala, Karnataka-Tamil Nadu-Kerala (UNESCO's MAB)	❖ **Agasthyamala BR = Shendurney WLS + Peppara WLS + Neyyar WLS + Kalakad Mundanthurai TR.** The reserve is home to **Kani tribes** from both Tamil Nadu and Kerala. ❖ **Major Fauna:** Nilgiri Tahr (EN)

Nilgiri, Tamil Nadu-Kerala (UNESCO's MAB, First to be included)	❖ Nilgiris (blue mountain) got their name from the **purplish blue flowers of Neelakurinji (blossoms once in 12 years).** ❖ The Nilgiri Sub-Cluster (UNESCO World Heritage Site) includes the **Mudumalai, Mukurthi, Nagarhole, Bandipur, and Silent Valley national parks, as well as the Aralam, Wayanad, and Sathyamangalam** wildlife sanctuaries. ❖ **Vegetation:** Tropical evergreen forests (western side of Western Ghats), montane sholas and grasslands (at high altitudes), semi-evergreen forests, moist deciduous forests, dry deciduous forests, and thorn forests. ❖ **Major Fauna:** Lion Tailed Macaque (EN), Nilgiri Tahr (EN), Malabar Giant Squirrel (LC), Nilgiri Langur (VU), etc.
Gulf of Mannar, Tamil Nadu (UNESCO's MAB)	❖ It lies between the west coast of Sri Lanka and the south-eastern tip of India, in the **Coromandel Coast region.** ❖ The chain of low islands and reefs known as **Ram Sethu** (Adam's Bridge), which includes Mannar Island, separates the Gulf of Mannar from Palk Bay, which lies to the north between Sri Lanka and India. ❖ The biosphere reserve comprises islands with estuaries, seagrasses, coral reefs, salt marshes, and mangroves. ❖ **Major Fauna: Dugong** (VU), Olive Ridley turtles (VU), etc.
Great Nicobar, Andaman & Nicobar Island (UNESCO's MAB)	❖ Great Nicobar BR = **Campbell Bay NP + Galathea NP.** ❖ **Vegetation:** tropical wet evergreen forests. ❖ **Major Fauna:** Dugong (VU), Saltwater Crocodile (LC), etc.

UNESCO WORLD HERITAGE SITES IN INDIA

❖ UNESCO World Heritage Sites are globally significant cultural, natural, or mixed landmarks protected under the 1972 UNESCO World Heritage Convention. India has 44 World Heritage Sites (as of July 2026). 44th UNESCO Site was Maratha Military Landscape.

❖ Sites are classified as cultural (e.g., monuments), natural (e.g., ecosystems), or mixed (e.g., cultural and ecological significance).

List of UNESCO World Heritage Sites in India

Name of WH Site (Natural)	State
Great Himalayan NP Conservation Area	Himachal Pradesh
Western Ghats	Maharashtra to Kerala
Nanda Devi and Valley of Flowers NP	Uttarakhand
Sundarbans National Park	West Bengal
Kaziranga National Park	Assam
Keoladeo National Park	Rajasthan
Manas Wildlife Sanctuary	Assam
Name of WH Site (Cultural)	**State**
Agra Fort	Uttar Pradesh
Ajanta Caves	Maharashtra
Ellora Caves	Maharashtra
Taj Mahal	Uttar Pradesh
Group of Monuments at Mahabalipuram	Tamil Nadu
Sun Temple, Konark	Odisha
Churches and Convents of Goa	Goa

Fatehpur Sikri	Uttar Pradesh
Group of Monuments at Hampi	Karnataka
Khajuraho Group of Monuments	Madhya Pradesh
Elephanta Caves	Maharashtra
Great Living Chola Temples	Tamil Nadu
Group of Monuments at Pattadakal	Karnataka
Santiniketan	West Bengal
Buddhist Monuments at Sanchi	Madhya Pradesh
Mountain Railways of India	West Bengal, T.N, H.P
Humayun's Tomb, Delhi	Delhi
Qutub Minar and Monuments, Delhi	Delhi
Mahabodhi Temple Complex at Bodh Gaya	Bihar
Rock Shelters of Bhimbetka	Madhya Pradesh
Champaner-Pavagadh Archaeological Park	Gujarat
Chhatrapati Shivaji Terminus (formerly Victoria Terminus	Maharashtra
Red Fort Complex	Delhi
Jantar Mantar	Jaipur
Hill Forts of Rajasthan	Rajasthan
Rani Ki Vav	Gujarat
Archaeological Site of Nalanda Mahavira at Nalanda	Bihar
The Architectural Work of Le Corbusier, an Outstanding Contribution to the Modern Movement	Chandigarh
Historic City of Ahmedabad	Gujarat
Victorian Gothic and Art Deco Ensembles of Mumbai	Maharashtra
Jaipur City	Rajasthan
Kakatiya Rudreshwara (Ramappa) Temple	Telangana
Dholavira, a Harappan City	Gujarat
Sacred Ensembles of the Hoysala	Karnataka
Name of WH Site (Mixed)	**State**
Khangchendzonga National Park (first Mixed Heritage site)	Sikkim

BIODIVERSITY HERITAGE SITE (BHS)

- **Well-defined areas that are unique and ecologically fragile ecosystems (terrestrial, coastal, marine, inland waters) having rich biodiversity comprising of any one or more of the following components:**
  - Species richness, High endemism, Presence of rare and threatened species, keystone species, and species of evolutionary significance, Presence of wild ancestors of domestic/cultivated species

❖ **Section 37 of the Biological Diversity Act, 2002 (BDA):** State Government local bodies may notify areas of biodiversity importance as BHS. Declaration of an area as BHS does not put any restriction on the prevailing practices and usages of the local communities. The purpose of BHS is to enhance the quality of life of the local communities through conservation measures.

List of Biodiversity Heritage Sites (BHS) in India

Name of the BHS Site (47)	State	Importance
Nallur Tamarind Grove	Karnataka	Believed to be a **relic of the Chola Dynasty**
Hogrekan	Karnataka	**Shola Vegetation,** adjoining Bhadra Wildlife Sanctuary and **Yemmedode Tiger Reserve** and serving as "Wildlife Corridor" between **Kudremukha and Bhadra Wildlife Sanctuary.**
University of Agricultural Sciences, GKVK Campus	Karnataka	**Greenest areas in Bengaluru**
Ambaraguda	Karnataka	Revenue land located between **Sharavathi Wildlife Sanctuary** and Someshwara Wildlife Sanctuary.
Glory of Allapalli	Maharashtra	Reserved forest
Tonglu BHS	Darjeeling, West Bengal	**Medicinal** Plant Conservation Areas
Dhotrey BHS under the Darjeeling Forest Division	West Bengal	**Medicinal** Plant Conservation Areas
Dialong Village	Manipur	The **Rongmei tribes** of Dailong and other villages of Tamenglong district were conserving forest in the form of sacred groves known as **"Raengan"**
Ameenpur Lake	Telangana	Urban Wetland
Majuli	Assam	**Largest river island in India,** famous for producing 100 varieties of paddy without application of fertilizers and pesticides.
Ghariyal Rehabilitation Centre, Lucknow	Uttar Pradesh	Conservation and rehabilitation of critically **endangered species of Gharial**
Chilkigarh Kanak Durga	West Bengal	**Sacred Grove**
Khlaw Kur Syiem KmieIng	Meghalaya	**Sacred Grove**
Mandasaru	Odisha	**Mandasaru gorge** is an adobe of 1563 species of plants, animals, and fungi spread over an area of 528 ha.
Purvatali Rai	Goa	**Sacred Grove,** Medicinal Plants
Naro Hills	Madhya Pradesh	Part of the Vindhya Hills region and a dry deciduous forest. Medicinal Plant including Dillenia pentagyna, Plumbago capensis, Psilotum nudum, Drosera burmanii, Alectra chitrakutensis, Cordia macleodii, Costus speciosus, Strychnos nux-vomica, Plumbago zeylancia etc.
Patalkot	Madhya Pradesh	Patalkot (Sanskrit for "Very Deep") is a valley in the Tamia tehsil of Chhindwara district in Madhya Pradesh, India. Patalkot is 78 km away from Chhindwara district headquarter. This valley is home to a tribal culture and enormous herbal wealth.

Asramam, Kollam	Kerala	BHS hosts a unique diversity of Mangrove species, Harbour Syzygium travancoricum (CR, IUCN List)
Bambarde Myristica Swamps	Maharashtra	Remnants of primaeval forests of the Western Ghats
Ganeshkhind Garden	Maharashtra	Holds a total of 610 germplasms of 49 crops including high economic value plants
Landorkhori	Maharashtra	The natural plantation of **Bori** (Zizyphus jujube) trees is unique and has survived since old ages.
Schistura Hiranyakeshi	Maharashtra	Declared as **Biological Heritage Site in 2021**
Baneswar Shiva Dighi	West Bengal	Offers refuge to Black Softshell Turtle Nilssonia nigricans listed under Appendix I of CITES and extinct in the wild category of IUCN.
Sural Bhatori Monastery	Himachal Pradesh	Sacred Grove
High Altitude Meadow (HUDAN BHATORI)	Himachal Pradesh	Important Horal species recorded in the area
Birch-pine Forest Patch(Nain Gahar)	Himachal Pradesh	Main trees are Himalayan Birch (Betula utilise) and Blue Pine (Pinus wallichiiana)
Baramura Waterfall	Tripura	Highest natural waterfall in Tripura
Unakoti	Tripura	Cultural and religious significance, Called **Angkor Wat of the North-East**
Silachari Caves	Tripura	**Only natural cave of Tripura**
Debbari or Chabimura	Tripura	Chabimura is famous for its panels of rock carvings on the steep mountain wall on the bank of river Gomati. These images date back to 15th-16th centuries AD.
Betlingshib & its surroundings	Tripura	It is the highest peak of Tripura and has the highest floristic diversity in Tripura. **Conservation:** It is habitat for several red listed flora and fauna. It is a medicinal plant conservation area.
Amarkantak	Madhya Pradesh	Situated on the **Maikal Mountain**
Hajong Tortoise Lake	Assam	Lake is a natural habitat of Critically Endangered freshwater 'Black Softshell turtle'
Borjuli Wild Rice Site	Assam	Good population of wild species of rice -Oryza rufipogon.
Arittapatti Biodiversity Heritage Site	Tamil Nadu	Rich biological and historical significance, 3 flagship **Raptor species - Laggar Falcon, Shaheen Falcon, Bonelli's Eagle**
Mahendragiri Hill Biodiversity Heritage Site	Odisha	The ancient temples of **Kunti, Shima, Arjuna and Yudhisthir** at Mahendragiri have been declared as protected monuments **under the Ancient Monument and Archaeological sites and Remains Act 1958 by the State Government.**
State Horticulture Research and Development Station	West Bengal	Rich Heritage of indigenous germplasm of horticulture and medicinal plants
Namthing Pokhari	West Bengal	Habitat for **Himalayan Newt**
Char Balidanga	West Bengal	-
Amkhoi Wood Fossil Park	West Bengal	Well preserved angiosperm wood fossil representing the existence of a forest dating back to the late Jurassic age.

Haldir Char Island	West Bengal	Mangrove swamp with tidal influence and sustains littoral fauna
Birampur-Baguran Jalpai	West Bengal	-
Tungkyong Dho	Sikkim	Believed to be one of the oldest natural **dho (lake)** directly related to the **Hee-Youngmingmoo clan of Lepcha community in Dzongu.**
Gandhamardan Hill	Odisha	Treasure trove of **medicinal plants.**

11 Conservation of Species and Sustainable Development

MAMMALS – CRITICALLY ENDANGERED (CR)

Species and Conservation Status	Features
Andaman White Toothed Shrew **IUCN:** CR	**Characteristics:** Small mouse-like shrew **Distribution:** Endemic to Andaman Islands (South Andaman) **Main Threats:** Habitat loss (Disasters, logging, climate change etc), and Hunting.
Jenkin's Shrew	**Characteristics:** Small-sized shrew, grayish or brown in color and largely insectivorous. **Distribution:** Endemic to South Andaman island. **Main threats:** Habitat loss (deforestation, forest fires) anthropogenic threats (infra, mining tourism, etc)
Nicobar Shrew	**Characteristics:** Small, largely insectivorous, nocturnal or crepuscular shrew. **Distribution:** Endemic to Great Nicobar Islands **Main Threats:** Predation, Tourism, mining, etc
Kashmir Stag/Hangul **IUCN:** CR **CITES:** Appx I **CMS:** Appx I	**Characteristics:** Asiatic sub-species of Central Asian red deer. **Distribution:** Endemic to Kashmir (now in Dachigam NP) **Main Threats:** Over-grazing, poaching, habitat loss and predation.
Himalayan Brown Bear **IUCN:** CR (Brown Bear is Least Concern LC) **CITES**: Appx I **CMS**: Appx I	**Characteristics:** One of the largest carnivores in the Himalayas, omnivorous, hibernates during winter. **Distribution:** North India (J&K, HP, Uttarakhand), north Pakistan, Nepal, Tibet, China, Central Asia, **(**Brown Bear Across Eurasia and North America). **Habitat:** Forests at high altitudes, alpine meadows **Threats:** Human-animal conflict, rapid habitat loss, poaching for fur, claws, and organs, etc.
Orangutan **IUCN:** CR **CITES:** Appx I	**Characteristics:** Great ape with reddish-brown fur, long arms, and high intelligence; primarily arboreal. Makes a tool with a stick to scrape insects from a hole in a tree or a log of wood. **Distribution:** Found in tropical rainforests of Borneo and Sumatra (Indonesia and Malaysia). **Threats:** Habitat destruction due to deforestation and palm oil plantations. ❖ Illegal wildlife trade. ❖ Poaching.
Pygmy Hog **IUCN:** CR **CITES:** Appx I	**Characteristics:** World's smallest wild pig, an indicator species of grassland habitats. **Distribution:** Found only in Manas Wildlife Sanctuary (Assam). **Threats:** livestock grazing, fires and poaching.

Species and Conservation Status	Features
Large Rock Rat/ Elvira Rat **IUCN:** CR	**Characteristics:** Social animals living in groups, omnivorous and highly active and agile. **Distribution:** Endemic to Eastern Ghats, Tamil Nadu. **Main Threats:** Habitat loss due to mining, quarrying, logging, and agriculture
Malabar Large-Spotted Civet **IUCN:** CR **CITES:** Appx III	**Characteristics:** Nocturnal and solitary animal that feeds on small mammals, birds, insects, and fruits. It has a distinct appearance with a long body, short legs, and a bushy tail. Its fur is reddish-brown with white spots, and it has a white stripe that runs from the nose to the forehead. **Distribution:** Endemic to southern Western Ghats **Main Threats:** Habitat loss due to agriculture & plantations, poaching, etc.
Namdapha Flying Squirrel **IUCN:** CR	**Characteristics:** Nocturnal, arboreal species that glides between trees instead of flying like birds or bats. It has reddish, grizzled fur with white above, a pale grey crown, an orangish patagium, and white underparts. **Distribution:** Restricted to Namdapha NP and other adjacent areas in Arunachal pradesh **Main Threats:** Habitat loss & climate change
Bactrian Double Humped Camel	**Distribution:** They are native to the harsh and arid regions of Central Asia.They occupy habitats in Central Asia from Afghanistan to China, primarily up into the Mongolian steppes and the Gobi desert. **A small population of Bactrian camels exists in the Nubra Valley of Ladakh.** They have been deployed by **Indian Army** recently.

Andaman Shrew

Malabar Civet

Double Humped Camel

MAMMALS – ENDANGERED (EN)

Species and Conservation Status	Features
Asian Elephant (EN) **IUCN:** EN **CITES:** Appx I **Three sub-species** ❖ Indian Elephant ❖ Srilankan Elephant ❖ Sumatran Elephant	**Characteristics:** Asian elephants are smaller than African elephants. The tusks are typically present only in males. They live in matriarchal herds and are led by older females, while the males are solitary. They are highly intelligent and social, they play a key ecological role. **Distribution**: They are found in forests and grasslands across South and Southeast Asia. In India they are found in the Himalayan foothills, western ghats and central India. India has the world's largest population of wild elephants with Karnataka having the highest population followed by Assam and Kerala. **Threats:** Poaching, Human wildlife conflict, Electrocution and train collisions, habitat loss,etc.

Tiger **IUCN:** EN **CITES:** Appx I	**Characteristics:** The Indian tiger also known as the Bengal tiger, is characterised by a vibrant orange coat marked by black stripes and a white underbelly. It is the largest wild cat in India.It is a solitary and territorial species. **Distribution:** They are found across diverse landscapes of South and South-east Asia. India is home to 75% of the world's wild tiger population as per the tiger census, 2022. These are widely distributed in India, with major populations in states like Madhya Pradesh, Uttarakhand, Karnataka, Maharashtra, and Assam. **Threats: Poaching, habitat loss and fragmentation, prey depletion, etc.**
Kharai camel **IUCN Status: EN**	**Characteristics:** Unique breed capable of swimming up to 3 km in seawater. ❖ Grazes on mangroves and other saline vegetation. ❖ Can be domesticated, often reared by local communities **Distribution:** Found in the coastal regions of Gujarat, especially in the Kutch region.
Dhole/Asiatic wild dog **IUCN:** EN **CITES:** Appx II	**Characteristics:** Dog-like carnivorous mammal,Highly social, lives in large clans. **Distribution:**Central, South, East and SE Asia. India has the largest population in the world, commonly found in Western ghats, Central Indian forests and forests of North east. **Habitat:** All grassland and forested regions. **Threat:** Habitat loss, large infra projects, diseases, etc.
Gee's Golden Langur **IUCN:** EN **CITES:** Appx I	**Characteristics:** Old world monkey with golden fur. **Distribution:** Western Assam and Southern Bhutan and Manas NP (India), Royal Manas NP (Bhutan), Black Mountains (Bhutan). **Threats:** Inbreeding depression, habitat loss, electrocution, vehicular accidents, etc.
Himalayan Musk Deer/ Kasturi **IUCN:** EN **CITES:** Appx I	**Characteristics:** Musk deer species, males secrete musk used in perfume industry, lacks antlers (distinguishing it from true deer) **Distribution:** Himalayas of Bhutan, India, Nepal, and China. In India found in Dachigam National park, Askot Wildlife sanctuary etc. **Threats:** Poaching for musk gland, habitat loss, etc.
Indian Hog Deer **IUCN:** EN, **CITES:** Appx III	**Characteristics**: It is a solitary creature and is sedentary and does not migrate. Males tend to be territorial and mark their territory with glandular secretions. This species exhibits sexual dimorphism. The females are slightly smaller than males and lack antlers. **Distribution:** Native to Indo-Gangetic Plain in Pakistan, India, Nepal, and mainland SE Asia. **Habitat:** Wet or moist tall grasslands, often associated with rivers,along the Terai region from Corbett to Assam. **Threats:** Habitat loss, poaching, feral dog attacks, etc
Lion-Tailed Macaque **IUCN:** EN **CITES:** Appx I	**Characteristics:** Arboreal old world monkey recognised by its silver-white mane that surrounds the head from the cheeks down to its chin. **Distribution:** Endemic to Western Ghats of South India, mainly in the states of Karnataka, Kerala, and Tamil Nadu. **Threats**: Habitat destruction and fragmentation, hunting, electrocution ,etc.
Nilgiri Tahr **IUCN:** EN	**Characteristics:** State animal of Tamil Nadu, only mountain ungulate in southern India. **Distribution:** Endemic to Nilgiri Hills in Western Ghats (Kerala and Tamil Nadu). **Threats**: Habitat loss due to rampant deforestation, competition with domestic livestock, hydroelectric projects in Nilgiri tahr habitat, and monoculture plantations and occasional hunting for its meat and skin.

Red Panda **IUCN:** EN **CITES:** Appx I	**Characteristics:** Arboreal mammal native to eastern Himalayas, southwestern China. Indicator species, umbrella species for Himalayan Ecosystem. Carnivorous but mainly feeds on bamboo, nocturnal and crepuscular. **Distribution:** Bhutan, India (Sikkim, West Bengal, Arunachal Pradesh, Meghalaya), Nepal, Myanmar, China. **Habitat:** Temperate montane forests with dense bamboo-thicket understorey. **Threats:** Forest fires, poaching and habitat loss.
Sangai (Brow-antlered deer) **IUCN:** EN, **CITES:** Appx I	**Characteristics:** Subspecies of **Eld's deer**, also known as Dancing deer. Restricted to Manipur, India. Endemic to Manipur, state animal of Manipur. **Distribution:** Found only at Keibul Lamjao National Park over the floating biomass in Loktak Lake (phumdi). **Threats:** Habitat destruction due to floods and invasive plants like Paragrass.
Western Hoolock Gibbon **IUCN:** EN **CITES:** Appx I	**Characteristics:** One of three hoolock gibbon species, inhabits Bangladesh, North East India, Myanmar (west of the Chindwin River). Only ape found in India. **Distribution:** Found in tropical evergreen rainforests, semi-evergreen forests, etc. **Threats:** Deforestation, hunting, etc.

Kharai Camel

Dhole

Sangai

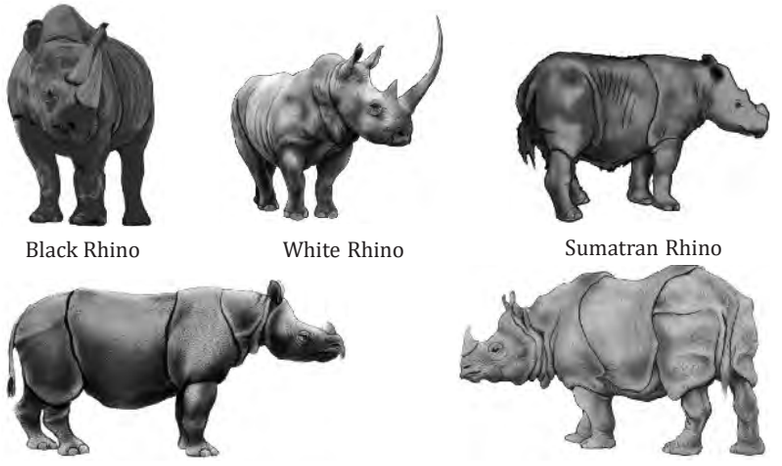
MAMMALS – VULNERABLE (VU)

Species and Conservation Status	Features
Asian Black Bear **IUCN:** VU **CITES:** Appx I	**Characteristics:** Himalayan Black Bear Subspecies of Asian Black Bear, Medium-sized arboreal bear species native to Asia. **Distribution:** Iran, north of the Indian subcontinent, Korean Peninsula, China, Russian Far East, Japan, Taiwan, SE Asia, Himalayan and NE regions.
Asiatic Lion **IUCN:** VU **CITES:** Appx I	**Characteristics:** The Asiatic lion is slightly smaller than its African counterpart. These lions live in smaller prides and are highly territorial. Lions do not have a particular breeding season. **Distribution:** They are found primarily in the Gir Forest of Gujarat and inhabit dry deciduous forests and grasslands. **Threats:** Habitat loss, human-wildlife conflict, and inbreeding.
One Horned Rhino: **IUCN:** VU **CITES:** Appx I **Other Asian Rhino Species** ❖ **Javan Rhino (CR)** ❖ **Sumatran Rhino (CR)** ❖ **White Rhino**	**Characteristics:** The one-horned rhinoceros , also known as the Indian rhinoceros, is a large herbivore with a thick, armor-like skin with deep folds and a single black horn. It is the second-largest rhinoceros species. These solitary animals are excellent swimmers and graze on grasses, aquatic plants, and fruits. **Distribution:** Native to the grasslands and swamps of northern India and Nepal **Threats:** Habitat loss and poaching. ❖ **White Rhino (only in protected sanctuary in Africa, 2 left , no females left)** ❖ **Javan rhino: Critically endangered.**

Asian Small-Clawed Otter **IUCN:** VU, **CITES:** Appx I	**Characteristics: Smallest otter species**, semi aquatic carnivorous mammal. **Distribution:** Native to South & SE Asia, found in Himalayan region, Western & Eastern Ghats in India.
Smooth coated Otter **IUCN:** VU, CITES: Appx I	**Characteristics:** Characterized by a very smooth, sleek pelage. They are strong swimmers and hunt in groups. **Distribution:** Is a freshwater otter that lives in South and Southeast Asia. In India, it can be found in major rivers south of the Himalayas. **Threats:** Loss of wetland habitat, poaching, water contamination by pesticides, etc.
Barasingha (Swamp Deer) **IUCN:** VU **CITES:** Appx I	**Characteristics:** Deer species native to the Indian subcontinent, state animal of MP and UP. **Distribution:** Isolated localities in north-east, north and central India, southwestern Nepal and famous in Kanha Tiger Reserve (MP). **Habitat:** Open forests, tall grasslands, mangroves.
Bonnet Macaque **IUCN:** VU, **CITES:** Appx II	**Characteristics:** Endemic macaque species found in southern India. **Distribution:** South of rivers Godavari and Tapti.
Capped Langur **IUCN:** VU **CITES:** Appx I	**Characteristics:** Arboreal herbivore, the capped langur is named for the dark patch of fur on its head that resembles a cap. **Distribution:** Found in Bangladesh, Bhutan, India (NE India south of Brahmaputra River), Myanmar. **Habitat:** Subtropical, evergreen, deciduous, bamboo, sub-montane forests, teak plantations.
Clouded Leopard **IUCN:** VU **CITES:** Appx I	**Characteristics:** A medium-sized cat with a distinctive cloud-like coat , state animal of Meghalaya. **Distribution:** Bangladesh, Bhutan, China, India, Nepal, SE Asia. **Habitat:** Highest population density in Dampa Tiger Reserve (Mizoram). **Threats:** Habitat destruction, poaching, commercial wildlife trade.
Eastern Hoolock Gibbon **IUCN:** VU **CITES:** Appx I	**Characteristics:** One of three species of hoolock gibbons, inhabits dense forests **Distribution:** Myanmar (east of the Chindwin River).In India they are found in Dibang valley in Arunachal Pradesh and Sasiya reserve Forest in Assam. **Habitat:** Evergreen, scrub, semi-deciduous forests, mountainous broadleaf, pine forests.
Fishing Cat **IUCN:** VU **CITES:** Appx II	**Characteristics:** Medium-sized wild cat, adept swimmer, nocturnal and apart from fish also preys on frogs, crustaceans, snakes, birds, and scavenges on carcasses of larger animals. **Distribution:** Plains of Ganga, Yamuna, Brahmaputra, Sundarbans delta, coastal wetlands along Bay of Bengal, Chilika lagoon. **Habitat**: Wetlands, mangroves, rivers, streams.
Four-Horned Antelope **IUCN:** VU, **CITES:** Appx III	**Characteristics:** Antelope with four horns,smallest antelope in Asia. **Distribution:** Endemic to India and Nepal, found from foothills of the Himalayas to the Deccan Plateau in India.
Gaur/Indian bison **IUCN:** VU, **CITES:** Appx I	**Characteristics:** Largest among wild cattle and bovids, social animals. State animal of Goa and Bihar. **Distribution:** South Asia, SE Asia, parts of Himalayan foothills, NE India, Eastern Ghats, Western Ghats
Nilgiri Langur **IUCN:** VU **CITES:** Appx II	**Characteristics:** Endemic to Nilgiri Hills, Silent Valley NP **Distribution:** Western Ghats (Karnataka, Tamil Nadu, Kerala) **Habitat:** Evergreen, semi-evergreen, moist deciduous, montane evergreen forests **Threats:** Habitat loss, human encroachment.

Nilgiri Marten **IUCN:** VU **CITES:** Appx III	**Characteristics:** Diurnal, arboreal and social creatures. **Distribution:** Endemic to Western Ghats **Habitat:** Evergreen forests, montane forest-grasslands **Threats:** Habitat loss, hunting for fur.
Sambar **IUCN:** VU,	**Characteristics:** India's largest deer, with a dark brown coat and majestic antlers. **Distribution:** Found throughout India, except high Himalayas, Kutch desert and coastal regions. **Threats:** Habitat loss, poaching, etc.
Sloth Bear **IUCN:** VU, **CITES:** Appx I	**Characteristics:** Native to the subcontinent, found in various habitats **Distribution:** Terai of India, Nepal, Bhutan, Sri Lanka **Habitat:** Moist and dry tropical forests, savannahs, grasslands
Snow Leopard (Keystone and Flagship species) **IUCN:** VU, **CITES:** Appx I	**Characteristics:** Keystone, indicator species in high-altitude Himalayan ecosystem **Distribution:** Central and South Asian mountain ranges, including Himalayas **Habitat:** Alpine and subalpine zones. **Threats:** Poaching, habitat loss and fragmentation, etc.
Stump-Tailed Macaque **IUCN:** VU, **CITES:** Appx II	**Characteristics:** Frugivore animals, with males bigger than females. **Distribution:** Native to South Asia, adept in various forest types. In India found in the region to the south of Brahmaputra river. **Habitat:** Tropical semi-evergreen, wet evergreen, moist deciduous forests

Types of Rhinos Found in the World



Rhinos of the World

Fishing Cat

Nilgiri Marten

MAMMALS – NEAR THREATENED (NT)

Species and Conservation Status	Features
Argali (Great Tibetan Sheep) **IUCN:** NT **CITES:** Appx II **CMS:** Appx II	**Characteristics:** World's largest wild sheep, native to Central Asia **Distribution:** East Asia, Himalayas, Tibet, Altai Mountains restricted in India to Ladakh, Hemis NP is famous. **Habitat:** Mountains, steppe valleys, rocky outcrops

Species and Conservation Status	Features
Asiatic Golden Cat **IUCN: NT**, **CITES:** Appx I	**Characteristics:** Medium-sized wild cat with their furs ranging in color from cinnamon to various shades of brown, and also gray and black (melanistic). They are solitary and territorial. Once considered nocturnal, have now been found to be **diurnal and crepuscular.** In parts of China they are known as the 'rock cat'. **Distribution**:Native to Indian subcontinent, SE Asia, China. In India found in NE India, recently sighted in Buxa Tiger Reserve in West Bengal.
Grey Slender Loris **IUCN: NT**, **CITES:** Appx II	**Characteristics:** Small nocturnal primate, arboreal, omnivorous. **Distribution:** India and Sri Lanka, found in specific regions of India such as Eastern Ghats,Western Ghats etc. **Habitat**: Tropical rainforests, dry forests, various forest types. **Threat**: They face a threat from poachers due to the misplaced belief that these animals have magical and medicinal powers.
Chiru (Tibetan Antelope) **IUCN: NT** **CITES:** Appx I	**Characteristics:** Native to Tibetan plateau. Famous for its Shahtoosh wool. **Distribution:** Tibetan plateau; famous in Karakoram (Nubra Shyok) WLS, Changthang Cold Desert WLS in Ladakh **Habitat:** High altitude plains, hills, plateaus, alpine, desert steppe, meadows. **Threats:** Poaching for shahtoosh wool, climate change, etc.
Grizzled Giant Squirrel **IUCN: NT** **CITES:** Appx II	**Characteristics:** Large tree squirrel, endemic to India and Sri Lanka **Distribution:** Kerala and Tamil Nadu, Southern India **Habitat:** Tropical dry deciduous and montane forests **Threats:** Habitat loss, hunting.
Himalayan Tahr **IUCN: NT**	**Characteristics:** Large ungulate, native to Himalayas **Distribution:** Himalayan region of India, Bhutan & Nepal
Indian Wild Ass/Khur **IUCN: NT** **CITES:** Appx II	**Characteristics:** Subspecies of Asiatic wild ass, native to South Asia. **Distribution:** Western India, southern Pakistan, Afghanistan, Iran **Habitat:** Semi-desert, grassland areas.
Malayan Giant Squirrel **IUCN: NT**, **CITES:** Appx II	**Characteristics:** Large tree squirrel, native to Indo-Malayan zone **Distribution:** Bangladesh, NE India, Nepal, Bhutan, China, SE Asia
Rusty-Spotted Cat **IUCN: NT**, **CITES:** Appx I	**Characteristics:** One of the smallest cats **Distribution:** India (excluding West Bengal and North East India), Nepal (Terai region), Sri Lanka
Siberian Ibex **IUCN: NT**, **CITES:** Appx III	**Characteristics:** Wild goat species, native to Central Asia **Distribution:** North India (J&K, Ladakh, Himachal Pradesh), Pakistan, Russia, China, Central Asian countries

Argali

Siberian Ibex

Chiru

Grey Slender Loris

MAMMALS – LEAST CONCERN (LC)

Species and Conservation Status	Features
Blackbuck **IUCN:** LC, **CITES:** Appx III	**Characteristics:** Indian antelope species, one of the fastest running animals on earth and worshipped by the Bishnoi community. **Distribution:** India (found in Gujarat, Rajasthan, Punjab and Haryana); extinct in Bangladesh, Pakistan **Habitat:** Grasslands, scrublands, agricultural margins **Threats:** Habitat destruction, illegal hunting
Chinkara **IUCN:** LC,	**Characteristics:** Indian gazelle, six subspecies **Distribution:** Ganges Valley to Deccan Plateau, Thar Desert, Rann of Kutch
Chital **IUCN:** LC	**Characteristics:** Spotted deer species **Distribution:** Indian subcontinent (excluding high Himalayas, NW India) **Habitat:** Various habitats except dense evergreen forests, desert
Indian Flying Fox **IUCN:** LC, **CITES:** Appx III	**Characteristics:** Largest flying bat, nocturnal, feeds on fruits **Distribution:** Indian subcontinent
Indian Giant Flying Squirrel **IUCN:** LC	**Characteristics:** Large flying squirrel. Many squirrels exhibit this behavior, known as **"caching"** to save food for future use. Indian squirrels primarily feed on fruits, nuts, and seeds but occasionally eat insects and small animals, making them omnivorous. **Distribution:** South Asia, SE Asia, patchy in Bangladesh, India, Sri Lanka **Habitat:** Deciduous and evergreen forests, plantations.
Rhesus Monkey **IUCN:** LC, **CITES:** Appx II	Hanuman langur is Gray langur distributed throughout India except NE India while Rhesus macaque occurs north of Godavari. In south of Godavari, it is replaced by Bonnet macaque.

OTHER MAMMALS

Species	Conservation Status & Features
Black Panther	**Characteristics:** Melanistic color variant of leopard or jaguar. **Distribution:** Found in Kabini WLS along the river Kabini.
Himalayan Wolf	**Characteristics:** Native to the Himalayas and the Tibetan Plateau. **Distribution:** Ladakh, Lahaul and Spiti (Himachal Pradesh), Uttarakhand. **Threats:** Climate change, killing by humans to protect their cattle.
Pangolin **Two species in India:** ❖ **Chinese Pangolin:** **IUCN:** CR ❖ **Indian Pangolin:** **IUCN:** EN	**Characteristics:** Nocturnal scaly-skinned insectivorous mammal; most trafficked mammal. **Threats:** Trafficking, hunting (meat and scales), habitat loss (mining, quarrying, agriculture).
Pig-Tailed Macaque	**Northern Pig-tailed Macaque (VU)** **Distribution**: Bangladesh, China, NE India, mainland SE Asia. **Habitat:** Tropical forests, coastal forest, swamp forest, montane forest. **IUCN**: VU | **CITES:** Appx II |
	Southern Pig-tailed Macaque (EN) **Distribution:** Maritime SE Asia (Thailand, Malaysia, Indonesia). **Habitat:** Mostly in rainforest, but also in plantations and gardens. **IUCN:** EN | **CITES:** Appx II

Porcupine **IUCN**: LC	**Indian Crested Porcupine (LC)** **Distribution:** North-west, entire Southern India. **Habitat:** Broad array of natural habitats, including plantations and gardens.
	Malayan Porcupine (LC) **Distribution:** Nepal, NE India, Bangladesh, China, SE Asia. **Habitat:** Various forest habitats, including agricultural areas. **Threats:** Indian Crested Porcupine is considered an agricultural pest and is trapped.

Pangolin

Porcupine

MARINE MAMMALS

Species and Conservation Status	Features
Dugong (Sea Cow) **IUCN:** VU **CITES:** Appx I **CMS**: Appx II	**Characteristics:** Herbivorous marine mammal, one of four living species of Sea cows. **Distribution:** East Africa, South Asia, SE Asia, East Asia, Australia and found in India in Palk Bay, Gulf of Mannar, Andaman and Nicobar Islands, Gulf of Kutch. **Threats:** Habitat loss (seagrass bed decline), hunting, marine pollution, etc.
River Dolphins **Major species:** ❖ **Indus River Dolphin/Bhulan (EN)** ❖ **Ganges River Dolphin/Susu (EN)** ❖ **Irrawaddy River dolphin (EN)** ❖ **Yangtze River Dolphin (CR)** ❖ **Tucuxi River Dolphin (EN)** ❖ **Amazon River Dolphin/Boto (EN)**	**Characteristics:** Dolphins are marine mammals. They surface to breathe air and give birth to live young. The gestation period of a dolphin lasts between 9 and 16 months. Dolphins make use of echolocation to navigate and hunt in the ocean. **Distribution:** River dolphins are found in the tropical and subtropical rivers of South America and Asia, as well as the coastal waters of Brazil, Argentina, and Uruguay. **In India, the distribution of river dolphins is as follows:** Ganges River Dolphin (National Aquatic Animal of india.) — The Ganga, Brahmaputra, Kosi, Karnaphuli, Sangu, and Karnali rivers. Indus River Dolphin — River Beas in India. Irrawaddy River Dolphin — Coastal areas like Lake Chilika, Bhitarkanika, Gahirmatha, Bay of Bengal, etc. **Threats:** Fishing, pollution, dams, habitat loss are causes for declining dolphin population.

DEER SPECIES IN INDIA

- India has the distinction of having the largest number of deer species in the world.
- Deer species of central India are known for their large size and big antlers. Whereas the species found in Eastern and Southern India have antlers smaller in size.
- Under Wildlife Protection Act 1972, only Chital and sambhar are under Schedule III (Moderate protection) remaing all other below deer species are under Schedule I (Highest protection).

Important Deer Species in India

Deer	IUCN Status	State Animal	Distribution
Hangul/Kashmir Stag	Critically Endangered	Jammu & Kashmir	Dachigam and areas above Srinagar in Kashmir Valley.
Hog Deer	Endangered	–	Alluvial grasslands of Terai from Corbett to Assam.
Thamin/Eld's Deer/ Sangai/Brow-Antlered Deer	Endangered	Manipur	Loktak Lake, Manipur.
Chital/Spotted Deer	Least Concern	Telangana	Widely distributed in India except the Northeast.
Swamp Deer/Barasingha	Vulnerable	Madhya Pradesh, Uttar Pradesh	Terai region of UP (swamp), Madhya Pradesh (hard ground).
Musk Deer (Himalayan/ Alpine)	Endangered	Uttarakhand	Found in the states of Jammu and Kashmir, Himachal Pradesh, Uttarakhand, Sikkim, and Arunachal Pradesh.
Sambhar	Vulnerable	Odisha	**Across India:** Himalayas, South India, Rajasthan, Northeast.

BIRDS – CRITICALLY ENDANGERED (CR)

Species and Conservation Status	Features
Baer's Pochard **IUCN:** CR, **CMS:** Appx II	**Characteristics:** Freshwater diving duck in eastern Asia. **Distribution:** South Asia and mainland SE Asia; found in NE India, WB, Odisha, and terai areas. **Threat:** Habitat loss and degradation, Drainage of wetlands for agriculture and rice cultivation is a major threat to the Baer's pochard's habitat.
Bengal Florican **IUCN:** CR **CITES:** Appx I	**Characteristics:** Rare bustard known for mating dance. **Habitat:** Grasslands interspersed with scrublands. **Distribution:** Native to the Indian subcontinent, Cambodia, and Vietnam. In India found in the states of Assam, Arunachal Pradesh and UP.
Black-Naped Pheasant Pigeon **IUCN:** CR	**Characteristics:** Feeds on seeds and fallen fruits. Recently sighted after 140 years in Papua New Guinea. **Distribution:** Large, terrestrial pigeon endemic to Fergusson Island (Papua New Guinea).
Bugun Liocichla **IUCN:** CR	**Characteristics:** Discovered in 2006; named in honor of Bugun community in West Kameng district. **Distribution:** Endemic to Arunachal Pradesh; Eaglenest WLS famous for it.
Great Indian Bustard aka Godawan **IUCN:** CR **CITES:** Appx I **CMS:** Appx I	**Characteristics:** Heaviest flying bird in the world; omnivorous flagship grassland species. **Distribution:** Native to Indian subcontinent, with the majority in Rajasthan. Also found in states of Gujarat, Maharashtra, MP, Andhra Pradesh, etc. **Mascot for the 13th COP of CMS in India (2020).** **Threats:** Collision with power lines, habitat loss, poaching are important threats
Himalayan Quail **IUCN:** CR	**Characteristics:** Last sighted before 1877; feared to be extinct. **Distribution:** Found only in Uttarakhand.

Jerdon's Courser **IUCN:** CR	**Characteristics:** Considered extinct until rediscovery in 1986. **Distribution:** Endemic to Eastern Ghats (Andhra Pradesh, Telangana). **Habitat:** Scrub jungles of Sri Lankamaleswara WLS.
Pink Headed Duck **IUCN:** CR **CITES:** Appx I	**Characteristics:** Last sighted in 1949; feared to be extinct. **Distribution:** Recorded in India & Myanmar.
Siberian Crane **IUCN:** CR **CITES:** Appx I **CMS:** Appx I	**Characteristics:** World's third rarest crane species; migrates to India during winter. **Distribution:** Resident of East and Central Asian Russia; migrates to India. **Habitat:** Most aquatic among crane species; wetlands. **Threats:** Pesticide pollution, habitat loss, hunting.
Sociable Lapwing **IUCN:** CR **CMS**: Appx I	**Characteristics:** Rarest and most threatened bird on Eurasian steppes. **Distribution:** Found in Central Asian countries; migrates to Sudan, Pakistan, North India during winter. **Habitat:** Dry grasslands, steppes, temperate deserts.
Spoon Billed Sandpiper **IUCN:** CR,**CMS**: Appx I	**Characteristics:** Known for spatula-shaped bill. **Distribution:** Breeds in Russia; migrates to South Asia and mainland SE Asia. In India found around coastal states of West Bengal, Odisha, Tamil nadu, etc. **Habitat:** Found in lagoon spits, estuaries and mudflats.
White-Bellied Heron **IUCN:** CR	**Characteristics:** Second largest heron species; brownish grey. **Distribution:** Found in India (Arunachal Pradesh, Assam), NE Bangladesh, Bhutan. **Habitat:** Inland swamp forests, forested rivers, submontane grasslands.
Yellow-Breasted Bunting **IUCN:** CR	**Distribution:** Breeds in Finland to Bering Sea; migrates to South Asia, SE Asia during winter. **Habitat:** Wet meadows with tall vegetation, scattered scrub, cultivated fields, and grasslands.
Vultures Species in India: ❖ **White rumped vulture (CR)** ❖ **Slender billed vulture (CR)** ❖ **Red headed vulture (CR)** ❖ **Indian vulture (CR)** ❖ **Egyptian vulture (EN)** ❖ **Bearded vulture (NT)** ❖ **Cinereous Vulture (NT)** ❖ **Himalayan Vulture (NT)** ❖ **Griffon vulture (LC)**	**Characteristics:** Vultures are a group of scavenging birds of prey that play a crucial ecological role by cleaning up carcasses and preventing the spread of disease. They belong to two groups: the Old World vultures found in Africa, Asia, and Europe, and the New World vultures found in the Americas. **Distribution:** Vultures are distributed across India in a variety of habitats, including grasslands, forests, open fields, and near garbage dumps and slaughterhouses: ❖ **Indian Vulture:** Breeds in peninsular India south of the Gangetic plain, and is also found in southeast Pakistan, Bangladesh, and Nepal. ❖ **Slender-billed Vulture:** Found in the northern parts of India, including the sub-Himalayan regions and the Gangetic plains. These vultures are characterized by their long, slender necks and dark, thin bills. ❖ **White-rumped Vulture:** Found in Panchkula, Haryana. ❖ **Eurasian Griffon:** Found in Surendranagar, Gujarat. ❖ **Egyptian Vulture:** Found in Bikaner, Rajasthan. ❖ **Cinereous Vulture:** Found in Bikaner, Rajasthan. ❖ **Bearded Vulture:** Found in Leh, Ladakh **Threats:** Loss of Natural Habitats, Food Scarcity and Contamination: Vultures face challenges related to food scarcity, and the available food sources are often contaminated. Pollution and the presence of harmful substances in their food contribute to health issues. and electrocution from Power Lines are causes of decline in the vulture population.

Himalayan Quail

Nicobar Megapode

Yellow breasted Bunting

Indian Skimmer

Jerdon Courser

OTHER IMPORTANT BIRDS

Species and Conservation Status	Features
Great Indian Hornbill **IUCN:** VU **CITES:** Appx I	**Characteristics:** Largest hornbill in India; state bird of Arunachal Pradesh and Kerala. **Distribution:** Native to Indian Subcontinent, SE Asia, China; in India - North-east India and Western Ghats. **Habitat:** Tropical evergreen forests.
Indian Skimmer **IUCN:** EN **CITES:** Appx I **CMS:** Appx II	**Characteristics:** One of the three species in the skimmer genus. **Distribution:** Major rivers of the Indian Subcontinent and Indo-China.
Nicobar Megapode **IUCN**: VU (Vulnerable)	**Characteristics:** Builds large mound nests with soil and vegetation and eggs hatched by heat from decomposition. **Distribution:** Endemic to Nicobar Islands. **Habitat:** Coastal forests.
River Tern **IUCN:** VU	**Characteristics:** Found along inland rivers in Iran, Afghanistan, Indian Subcontinent, SE Asia. **Habitat:** Rivers and freshwater lakes. **Threats:** Hunting, pollution, invasive species.
Sarus Crane **IUCN:** VU **CITES:** Appx II	**Characteristics:** Large nonmigratory crane; tallest flying bird in the world. **Distribution:** Indian subcontinent, SE Asia, Australia; in India - Himalayan foothills, Northwest India, Central India. **Habitat:** Open wet & dry grasslands, agricultural fields.
Black Necked Crane **IUCN:** NT **CITES:** Appx I **CMS:** Appx I	**Characteristics:** State bird of UT of Ladakh; native to Ladakh, Sichuan, Tibet; migrates to Arunachal Pradesh and Bhutan during winters. **Habitat:** Inland grassy wetlands at high elevation.
Painted Stork **IUCN:** NT	**Characteristics:** Large shore bird endemic to Indian subcontinent and SE Asia. **Distribution:** River plains of Indian subcontinent, mainland SE Asia. **Habitat:** Freshwater marshes, lakes, reservoirs, flooded fields, river banks, etc. **Threats:** Hunting, pollution, invasive species.

Common Hill Myna **IUCN:** LC **CITES:** Appx II	**Characteristics:** Native to eastern India, mainland SE Asia; state bird of Chattisgarh. **Habitat:** Evergreen and wet deciduous forests; prefers areas with high rainfall and humidity. **Threats:** Overexploitation for pet trade.
Greater Flamingo **IUCN:** LC **CITES:** Appx II	**Characteristics:** Most widespread and largest flamingo species. **Distribution:** Africa, Indian subcontinent, Middle East, southern Europe; in India - almost all over (except high-altitude areas, East and NE India). **Habitat:** Shallow eutrophic waterbodies such as saline lagoons, saltpans, saline or alkaline lakes.
Himalayan Bulbul **IUCN:** LC	**Characteristics:** Songbird in the bulbul family. **Distribution:** Endemic to the Himalayan region of the Indian subcontinent.

River Tern

Painted Stork

FISHES

Species and Conservation Status	Features
Ganges Shark **IUCN:** CR	**Characteristics:** Freshwater shark **Distribution:** Endemic to India, Bangladesh, also found in Myanmar, Malaysia, Indonesia
Humpback Mahseer **IUCN:** CR	**Characteristics:** Large freshwater fish, endemic to Cauvery River basin **Distribution:** Cauvery River basin, Western Ghats **Threat**: Habitat loss, overfishing, and pollution.
Golden Mahseer **IUCN:** Endangered (EN)	**Characteristics:** Large golden-colored fish, tough sport fish **Distribution:** Basins of Indus, Ganges, Brahmaputra rivers **Threat**: Habitat loss, overfishing, and pollution, dam construction etc.
Magur **IUCN:** Endangered (EN)	**Characteristics:** Walking catfish endemic to India, Nepal, and Bangladesh **Habitat:** Freshwater, brackish water, flooded rice fields
Blue Finned Mahseer **IUCN:**Least Concern (LC)	**Characteristics:** Large freshwater fish, also known as Black or Deccan Mahseer **Distribution:** Deccan Peninsula, Sri Lanka and Cauvery river. **Habitat:** Prefers cool, fast-flowing, rocky streams, also found in rivers, lakes, reservoirs
Helicopter Catfish **IUCN:** Vulnerable (VU)	**Characteristics:** Freshwater catfish native to South and SE Asia **Distribution:** South and SE Asia **Habitat:** Freshwater bodies, tidal waters

Magur Walking Catfish

Golden Mahseer

REPTILES

Species and Conservation Status	Features
Gharial **IUCN: Critically Endangered (CR)** Other important crocodiles: **Mugger (VU)** **Salt Water Crocodile (LC)**	**Characteristics:** Gharial is characterised by its long, slender snout with sharp interlocking teeth, adapted for catching fish. Adult males have a bulbous growth, called a "ghara," on the snout tip, used for vocalization and attracting mates. **Distribution:** Gharials inhabit deep, fast-flowing rivers like Chambal, Son, Gandak, Ghaghara etc in northern India and Nepal. They primarily bask on sandy riverbanks and lay eggs in burrows. **Threats:** Habitat loss, pollution, and fishing net entanglements.
Hawksbill Turtle **IUCN: Critically Endangered (CR)** **CITES:** Appx 1	**Characteristics:** The hawksbill turtle is marine turtle known for its striking, overlapping amber-colored scales on its heart-shaped shell, prized for "tortoiseshell" products. It feeds on sponges, algae, and other invertebrates, playing a crucial role in maintaining coral reef health. **Distribution:** Hawksbills are found in tropical and subtropical waters of the Atlantic, Indian, and Pacific Oceans, often near coral reefs, lagoons, and rocky coastlines. In India they are found in Andaman and Nicobar Islands. **Threat:** Loss of nesting and feeding habitats, excessive egg collection, fishery-related mortality, pollution,wildlife trade and coastal development.
Olive Ridley Turtle **IUCN: Critically Endangered (VU)** **CITES:** Appx 1	**Characteristics:** It is a small to medium-sized marine turtle known for its olive-green, heart-shaped shell. It is best recognized for its unique mass nesting behavior called "arribada," where thousands of females come ashore simultaneously to lay eggs. They are highly migratory, traveling vast distances between feeding and nesting grounds. **Distribution:** Found in warm, tropical oceans waters. In India,they are primarily found along the eastern coast, with major nesting sites in Odisha at Gahirmatha Beach, Rushikulya, and Devi River Mouth. Other important nesting areas include Andhra Pradesh (Kakinada and Krishna estuary), Tamil Nadu (Chennai coast and Nagapattinam), and sporadically in the Sundarbans of West Bengal. **Threats:** habitat loss from coastal development, bycatch in fishing nets, marine pollution, and illegal egg poaching.
Asian Giant Tortoise **IUCN: Critically Endangered (CR)**	**Characteristics**: Largest tortoises in mainland Asia **Distribution:** Found in Bangladesh, India, Indonesia, Malaysia.
Star Tortoise **IUCN:** Vulnerable (VU)	**Characteristics:** Medium-sized tortoise species **Habitat:** Parts of India below West Bengal and Gujarat

PLANTS

Species and Conservation Status	Features
Indian Rosewood **IUCN:** Vulnerable (VU)	**Characteristics:** Large evergreen tree native to low-elevation monsoon forests of south India. Drier subpopulations are deciduous. **Distribution:** Native to India (Tamil Nadu, Karnataka, Andhra Pradesh, Uttar Pradesh, and Sikkim)
North Indian Rosewood **IUCN:** Least Concern (LC)	**Characteristics:** Fast-growing, hardy, medium to large deciduous tree native to the foothills of the Himalayas. **Distribution:** Native to the Indian subcontinent and southern Iran. Endemic to tropical Himalayas.
Red Sanders (EN)	**Characteristics:** Red sanders, also known as red sandalwood, is a rare and valuable deciduous tree. It is renowned for its dark reddish heartwood, prized for its rich color, durability, and use in high-value items like musical instruments, furniture, and traditional medicine. **Distribution:** It is endemic to the southern Eastern Ghats of India. Red sanders thrive in dry, rocky soils and semi-arid climates. **Threat:** Overexploitation for its wood, combined with habitat loss
Sandalwood (EN)	**Characteristics:** Sandalwood is a highly valued evergreen tree known for its fragrant, durable heartwood. It is renowned for its aromatic heartwood, which is used in perfumes, incense, and traditional medicines. Its essential oil is known for its soothing, anti-inflammatory properties. **Distribution:** It thrives in dry, well-drained soils, predominantly in India, Australia, and parts of Southeast Asia. In India it is found in most parts of Karnataka, Maharashtra, Andhra Pradesh, etc. **Threat:** Overharvesting and illegal logging
Schedule III of WPA after The Wild Life (Protection) Amendment Act, 2022 - Plant	**Scientific Name** — **Common Name** 1. Strobilanthes kunthianus — Neelakurinji 2. Coptis teeta — Gold threat, Mishmi teeta 3. Coscinium fenestration — Tree turmeric 4. Taxus wallichiana — Himalayan Yew 5. Vanda coerulea — Blue vanda 6. Nepenthes khasiana — Pitcher plant 7. Renanthera imootiana — Red vanda 8. Ipsea malabarica — Daffodil orchid 9. Podophyllum hexandrum — Indian podohyllum 10. Dolomiaea costus — Kuth

NATIVE WILDLIFE OF PROMINENT COUNTRIES

Country	Species Naturally Found
India	Black-necked Crane, Flying Squirrel, Snow Leopard, Indian Elephant, Bengal Tiger.
Australia	Kangaroo, Koala, Tasmanian Devil, Emu, Platypus.
Brazil	Jaguar, Giant Anteater, Capybara, Howler Monkey, Sloth.
United States	American Bison, Bald Eagle, Grizzly Bear, Prairie Dog.
South Africa	African Elephant, White Rhino, Leopard, Meerkat, Springbok.

INVASIVE SPECIES

Invasive Plant Species

Invasive plant species are non-native plants that spread rapidly in new environments, outcompeting native vegetation and disrupting ecosystems.

- **Acacia**
  - Evergreen drought-resistant plant native to Africa and Australasia.
  - Used for tannin production, contributing to habitat destruction in the Western Ghats.
- **Billygoat Weed**
  - Native to Tropical America, medicinal properties, but invasive outside its native range.
  - Considered a moderate weed in rice cultivation in Asia.
- **Carrot Grass (Congress Grass)**
  - Native to the American tropics, invasive in India, Australia, and parts of Africa.
  - Produces allelopathic chemicals that suppress crop and pasture plants.
  - Releases allergens causing allergies in humans and domestic animals.
- **Eucalyptus**
  - Fast-growing evergreen tree native to Australia.
  - Medicinal properties, acts as an insect repellent.
  - Invasive species outside its native range, rapidly reproduces, impacting native fauna.
- **Forked Fanwort**
  - Pink flowering submerged aquatic plant native to South America.
  - Invasive species in freshwater, commonly used in aquariums, displacing native aquatic plants.
- **Lantana**
  - Flowering plant native to the American tropics, invasive once introduced into habitats.
  - Toxicity affects livestock, poisonous when consumed.
- **Mexican Prickly Poppy**
  - Herb tolerant to drought and poor soil, naturalized widely outside Mexico.
  - Seeds resemble mustard seeds, used in adulteration, rendering mustard poisonous.
- **Mikania Micrantha**
  - Tropical perennial creeper native to the Americas, invasive weed in high humidity regions.
  - Medicinal properties, but grows vigorously, suppressing the growth of various plant species.
- **Prosopis Juliflora (Ganda Babool)**
  - Small tree native to Mexico, invasive in Africa, Asia, Australia, and more.
  - Rapid growth depletes water resources, prevents the growth of native species, and hampers animal movement.
  - Introduced in Banni grasslands, causing water depletion, aggravating droughts, and affecting pastures.
- **Water Hyacinth**
  - Native to South America, water hyacinth is a free-floating perennial hydrophyte found in tropical, subtropical, temperate, and rainforest zones.
  - Invasiveness: It's an invasive species worldwide, including regions like Bangladesh (known as 'German Weed'), South Africa ('Florida Devil'), and Sri Lanka ('Japanese Trouble'). Its rapid growth and reproduction cover ponds and lakes, depleting oxygen and harming aquatic biodiversity, especially in human-affected water bodies.

Sea Buckthorn

- Found in Ladakh, has received GI tag.
- **Soil Erosion and Desertification:** The plant's deep and extensive root system helps control soil erosion and combats desertification.
- **Adaptability:** Grows in cold, high-altitude regions like the Himalayas, thriving in arid and challenging environments.
- **Nutritional Value:** Rich in vitamins (especially Vitamin C) and antioxidants, making its fruit highly nutritious and beneficial.

Nostoc: A Biofertilizer

- **Type**: Cyanobacterium (Blue-Green Algae).
- **Role**: Capable of nitrogen fixation, converting atmospheric nitrogen into a form usable by plants.
- **Benefits**: Enhances soil fertility, particularly in paddy fields and other nutrient-deficient soils.
- **Ecological Significance**: Supports sustainable agriculture by reducing the need for chemical nitrogen fertilizers

Birds in India

- Ceylon Frogmouth, Coppersmith Barbet, Gray-chinned Minivet, White-throated Redstart

Notable Insects in Indian Biodiversity

- Cicada, Froghopper and Pond skate

Animals with Defensive Rolling Behavior

- **Hedgehog:** Rolls up to protect its vulnerable parts with spines.
- **Marmot:** Does not roll up; instead, it relies on burrowing for safety.
- **Pangolin:** Rolls up into a ball, protecting itself with hard scales.

Filter Feeder

- A filter feeder that extracts nutrients from water by filtering out plankton and organic particles.

  Example: Oysters and others shown below.

Basking shark

Whale shark

Baleen shales

Greater Flamingos

Sandcastle worm

Poisonous Species Among Butterflies, Fish, and Frogs

- **Butterflies:** Some species, like the Monarch butterfly, are toxic due to the consumption of poisonous plants (milkweed) during the caterpillar stage.
- **Fish:** Several species, such as Pufferfish, are highly poisonous due to the presence of tetrodotoxin.
- **Frogs:** Poison dart frogs are known for their potent toxins, used as a defense mechanism.

Invasive Fish and Amphibian Species

- **African Catfish**
  - **Species:** Nocturnal air breathing catfish native to Africa and the Middle East.
  - **Habitat:** Thrives in freshwater lakes, rivers, and swamps, adapting to turbid, low-oxygen waters. Illegally bred in polluted ponds and lakes.
  - **Threat:** A voracious carnivore, it endangers indigenous fish species, prompting the Central government to ban catfish farming (breeding, transportation, and sale) in 2000 due to health and environmental hazards.
- **Indian Bullfrog**
  - **Species:** Large fork-tongued frog prevalent in South and SE Asia.
  - **Distribution:** Introduced to Maldives, Madagascar, and India's Andaman Islands.
  - **Threat:** To native wildlife, including fish, lizards, and frogs. Its invasive nature makes it a concern for biodiversity conservation efforts.

IMPORTANT TREES AND THEIR CHARACTERISTICS

Aspect	Palm	Moringa (Drumstick Tree)	Tamarind Tree	Neem Tree	Gucchi
Native Region	Not native to Southeast Asia; originally from West Africa.	Native to India and Africa.	Native to tropical Africa, not endemic to South Asia.	Native to the Indian subcontinent.	Found in Himalayan forest areas.
Industrial Uses	Raw material for industries producing lipstick and perfumes. Used in biodiesel production.	Seeds used in biofuel production. Leaves, pods, and seeds have nutritional and medicinal uses.	Tamarind is collected as minor forest produce in India. Seeds used for biofuels.	Neem oil used as a pesticide. Seeds used for biofuels. Oil used in hospital detergents and pharmaceuticals.	Gucchi is a high-value edible fungus used in gourmet cuisine; not commercially cultivated.

Environmental Importance	❖ Widespread plantation impacts biodiversity.	❖ Fast-growing tree with drought resistance.	❖ Tamarind trees contribute to forest ecosystems.	❖ Eco-friendly alternative to chemical pesticides.	❖ Promotes forest ecosystem health; grows naturally without human intervention.
Export Potential	❖ Major exporter globally (India imports palm oil).	❖ India exports seeds and pods.	❖ India exports tamarind and seeds.	❖ Limited export relevance; primarily local applications.	❖ Highly valued in international markets for its flavor and rarity.
Additional Notes	❖ Extensively used in food and cosmetic industries globally.	❖ Popular in agroforestry for its economic and ecological benefits.	❖ Widely used in traditional Indian cuisine.	❖ Multifunctional tree with environmental, medicinal, and industrial applications.	❖ Grows in Himalayan forests; collection is labor-intensive, contributing to its high price.

MAJOR ENERGY SOURCES

- **Conventional Non-Renewable:** Coal, Oil, Natural Gas: Fossil fuels found underground.
- **Non-Conventional Renewable:** Solar Energy, Hydro Power, Wind Energy, Nuclear Energy, Hydrogen Energy, Geothermal Energy, Biogas, Tidal Energy, Biofuel.

Energy Source	Production/Process	Applications	Key Features/Challenges
Solar Energy	❖ PV cells convert sunlight into electricity. ❖ Solar thermal systems concentrate sunlight to heat fluids for power.	Electricity generation, heating.	Renewable, low emissions; efficiency depends on sunlight availability.
Hydro Power	Dams capture flowing water energy to turn turbines connected to generators.	Electricity generation.	Reliable, renewable; potential for ecological disruption.
Wind Energy	Wind turbines convert wind's kinetic energy into electricity through blade rotation.	Electricity generation.	Clean, renewable; depends on wind speed and location.
Nuclear Energy	❖ Fission: Splitting atoms releases energy for heat/electricity. ❖ Fusion: Combines atoms at high temperatures (future potential).	Electricity generation.	High energy output; concerns about radioactive waste and safety.
Hydrogen Energy	❖ Electrolysis splits water into hydrogen and oxygen. ❖ Steam methane reforming extracts hydrogen from natural gas.	Fuel cells, industrial processes.	Clean, versatile; production can be energy-intensive.
Biogas	Produced by anaerobic digestion of organic matter (animal waste, crop residues, sewage).	Heating, electricity generation.	Renewable; methane emissions can be captured but requires proper infrastructure.

Biofuel	Derived from biomass through fermentation, transesterification, or thermochemical processes.	Vehicle fuel, power generation.	Reduces emissions; may compete with food production and impact land use.
Biomass Conversion	❖ Direct burning for cooking/ electricity. ❖ Conversion to ethanol/methane via fermentation or anaerobic digestion.	Cooking, heating, electricity, fuel production.	Can deplete soil nutrients; energy-intensive ethanol production.
Solid Waste	Sorted and combusted for energy recovery.	Waste-to-energy plants.	Reduces landfill use; burning causes air pollution, especially plastics.
Geothermal Energy	Utilizes steam from underground reservoirs or hot springs to generate electricity.	Electricity generation, heating.	Renewable, reliable; potential pollution from hydrogen sulfide and toxic minerals.
Tidal Energy	Dams built across bays/estuaries control water flow to drive turbines.	Electricity generation.	Predictable; may disrupt habitats and alter natural water flows.
Methanol and Ethanol	❖ Methanol: Produced from natural gas/biomass. ❖ Ethanol: Derived from fermentation of biowaste/food crops.	Clean fuels, solvents, fuel additives.	Cleaner-burning; reduces pollution but production may compete with food resources.
Liquefied Petroleum Gas (LPG)	By-product of natural gas processing and petroleum refining.	Heating, cooking, vehicle fuel.	Portable, efficient; odorized for leak detection.
Compressed Natural Gas (CNG)	Compressed methane stored in tanks. Compressed Natural Gas (CNG) is primarily composed of Methane (CH_4), making it a cleaner and environmentally friendly fuel. (RAS 2021/2013)	Vehicle fuel.	Cleaner and cheaper than traditional fuels; requires specialized storage.

Distributed Energy Resources

Distributed energy resources are small, modular, energy generation and storage technologies that provide electric capacity or energy where you need it. Typically producing less than 10 megawatts (MW) of power, DER systems can usually be sized to meet your particular needs and installed on site.

Examples of distributed energy resources that can be installed include:

- **roof top solar photovoltaic units {**A photovoltaic (solar) cell converts solar energy directly into electrical energy through the photovoltaic effect. (RAS 2016)}
- wind generating units
- **battery storage**
- batteries in electric vehicles used to export power back to the grid
- combined heat and power units, or tri-generation units that also utilise waste heat to provide cooling
- **biomass generators**, which are fuelled with waste gas or industrial and agricultural by-products.
- open and closed cycle gas turbines
- reciprocating engines (diesel, oil)
- hydro and mini-hydro schemes
- **fuel cells**

BIOFUEL

Biofuels are hydrocarbon fuels produced from organic matter (living or once-living material) in a short period.

- **Types include**
  - **Solid**: Wood, manure
  - **Liquid:** Bioethanol, Biodiesel
  - **Gaseous**: Biogas
- **Environmental Impact:** Emit less CO_2 than conventional fuels, making them a viable option to reduce transport sector emissions. They constitute about 3% of global road transport fuels.

National Policy on Biofuels 2018

- **Blending Targets**
  - Target of 20% ethanol blending in petrol and 5% biodiesel blending in diesel by 2030.
  - **Current Percentages:** 2% for petrol and less than 0.1% for diesel.
- **Categorization:**
- The policy categorizes biofuels into Four types:

- **First-Generation (1G) Biofuels:** Ethanol and biodiesel derived from food crops like sugarcane and vegetable oil.
- **Second-Generation (2G) Biofuels:** Ethanol produced from non-food feedstocks like agricultural residues and waste.
- **Third-Generation (3G) Biofuels:** Advanced biofuels from algae, and bio-CNG.
- **Fourth-generation biofuels:** They are advanced biofuels produced using genetically engineered microorganisms or algae that can capture and store atmospheric CO_2 during fuel production, making them carbon-negative. (RAS 2024)
- The Policy expands the scope of raw material for ethanol production by allowing use of Sugarcane Juice, Sugar containing materials like Sugar Beet, Sweet Sorghum, Starch containing materials like Corn, Cassava, Damaged food grains like wheat, broken rice, Rotten Potatoes, unfit for human consumption for ethanol production.

❖ **Ethanol Blended Petrol (EBP) Programme:**
- Aims for 20% ethanol blending and 5% biodiesel blending by 2030.
- **Revised E20 target for 2025;** phased rollout from April 2023.

Some Important Biofuels (RAS 2013)

Biofuel Type	Source and Production	Key Features	Applications
Bioethanol	Derived from corn and sugarcane through fermentation.	Contains about two-thirds of the energy of petrol. Improves combustion performance and reduces carbon monoxide and sulfur oxide emissions.	Mixed with petrol to enhance fuel efficiency and reduce emissions.
Biodiesel	Produced from vegetable oils (e.g., soybean, palm), waste oils, and animal fats using transesterification.	Emits fewer harmful gases than conventional diesel. Has intrinsic lubricating properties, low toxicity, and is biodegradable.	Alternative to diesel fuel; used in blends (e.g., B2, B5, B100).
Biogas	Created through anaerobic decomposition of organic matter (sewage, animal and human waste).	Composed mainly of methane (50-65%) and carbon dioxide (35-50%), with traces of other gases. Can be purified into Compressed Bio-Gas (CBG).	Used for heating, electricity generation, and as automotive fuel.
Biobutanol	Produced similarly to bioethanol through starch fermentation.	Highest energy content among gasoline alternatives. Reduces emissions when added to diesel. Also used as a solvent and perfume base.	Added to diesel fuel; industrial solvent in the textile industry and as a base for perfumes.
Biohydrogen	Produced through processes like pyrolysis, gasification, or biological fermentation.	Clear, colorless, and biodegradable. Potential alternative to fossil fuels, with high energy efficiency.	Used for fuel cells, transportation, and industrial applications.

Sustainable Alternative Towards Affordable Transportation Scheme (SATAT)

❖ Encourages entrepreneurs to **set up CBG plants for green automotive and industrial fuel.**

❖ Aims to address urban air pollution, enhance farmers' income, and promote organic farming.

Sustainable Aviation Fuel (SAF)

❖ **Sustainable Aviation Fuel (SAF)**, also referred to as **bio-jet fuel,** is created using **domestically developed methods** using **cooking oil** and **oil-rich seeds from plants.**

❖ Agricultural residues, corn grain, wastewater treatment sludge, and wood mill waste—can be used as feedstock for producing Sustainable Aviation Fuel (SAF).

HYDROGEN AS A FUEL

- **Clean Source:** Zero-emission fuel, produces only water vapor as a byproduct.
- **Hydrogen Economy Vision:** Utilizing hydrogen as a low-carbon energy source to decarbonize sectors like steel, cement, and transportation.

Properties of Hydrogen

- **Abundance and Characteristics:**
  - Most abundant chemical substance in the universe.
  - Nontoxic, odorless, tasteless, colorless, and highly combustible diatomic gas (H2).
- **Energy Carrier:**
  - Hydrogen is not an energy source but an energy carrier.
  - Produced through processes like electrolysis, splitting water into hydrogen and oxygen.

Potential

- Abundance and Efficiency
  - Renewable, non-polluting fuel producing water as the only by-product.
  - More fuel-efficient compared to diesel or gas.

Challenges

- **Production Challenges:** Transportation and storage challenges, safety concerns due to high reactivity.
- **Environment Constraints:** Energy-intensive **production methods with a high carbon footprint.**
- **Economic Challenges:** Cost of electrolysers, critical minerals access, and scaling up production.

Types of Hydrogen

Hydrogen	Source/Process
Brown Hydrogen	Coal without carbon sequestration.
Grey Hydrogen	Natural gas/fossil fuels without carbon sequestration.
Blue Hydrogen	Natural gas/fossil fuels with carbon sequestration.
Green Hydrogen	Produced using renewable energy without carbon sequestration.
Pink Hydrogen	Generated through electrolysis using electricity produced by nuclear energy. Sometimes referred to as purple or red hydrogen.
Turquoise Hydrogen	Made through methane pyrolysis, producing hydrogen and solid carbon. Production has not yet been proven at scale.
Yellow Hydrogen	Made through electrolysis powered by solar energy.
White Hydrogen	Naturally-occurring hydrogen found in underground deposits and extracted through fracking.

Current Status in India

- **Production and Usage**
  - Majority produced through methane reforming, contributing to CO_2 emissions.
  - National Hydrogen Energy Road Map (NHERM) adopted in 2006.
  - National Hydrogen Energy Mission (NHM) announced in the 2021-22 Union Budget.
- **Hydrogen Blended Natural Gas:** Plan to blend 15% green hydrogen with piped natural gas.
- **Efficiency Ranking: Electric Vehicles > Hydrogen > Diesel > Petrol vehicles** (in decreasing order of overall efficiency)

National Green Hydrogen Mission (NGHM)

- Green hydrogen is hydrogen produced by the electrolysis of water, using renewable electricity. Production of green hydrogen causes significantly lower greenhouse gas emissions than production of grey hydrogen, which is derived from fossil fuels without carbon capture.
- **Launched in 2023**
  - Aims to make India an energy-independent nation and a green hydrogen hub.
  - Facilitates demand creation, production, and export of green hydrogen.
- **Salient Features**
  - Targets green hydrogen production capacity of at least 5 MMT per annum by 2030.
  - **SIGHT Program:** Incentives for manufacturing of electrolysers and production of green hydrogen

Hydrogen Fuel Cell

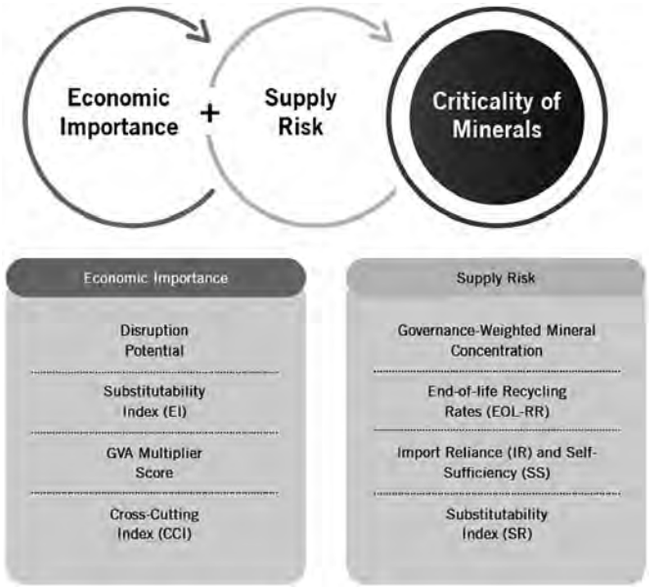
- **Fuel Cell Operation**
  - Uses the chemical energy of hydrogen or **other fuels to cleanly and efficiently produce electricity.** If hydrogen is the fuel, the only products are electricity, water, and heat.
  - Anode, cathode, and electrolyte components.
- **Advantages and Challenges**
  - More efficient than thermal power plants.
  - **Expensive production due to costly catalysts like platinum or palladium.**

CRITICAL MINERALS IN THE GREEN TRANSITION

- **Demand for Critical Minerals:** Solar PV plants, wind farms, and electric vehicles require minerals

like **cobalt, copper, lithium, nickel, and rare earth elements (REEs).**

- **Significance of Minerals:** Lithium, nickel, cobalt, manganese, graphite, and REEs are crucial for battery performance, longevity, and energy density.
- **Supply Chain Challenges:** The global supply chain for critical minerals is concentrated, posing a supply risk due to uneven distribution.



Measures Taken by India

- **Geological Survey Discovery:** The Geological Survey of India discovered 5.9 mt of lithium deposits in J&K, the first such discovery in the country.
- **KABIL for Mineral Security**
  - **Formation:** The Ministry of Mines created Khanij Bidesh India Ltd. (KABIL) in collaboration with NALCO, HCL, and MECL to ensure mineral security.
  - **Objectives:** Aims to ensure a consistent supply of critical and strategic minerals to the Indian domestic market, with a focus on minerals like lithium and cobalt.
  - **Functions:** KABIL is responsible for identification, exploration, development, mining, and processing of strategic minerals overseas for commercial use.

Indian Renewable Energy Development Agency (IREDA)

- IREDA is a **Mini Ratna (Category – I) Public Limited Government Company under the Ministry of New & Renewable Energy.**
- Established in **1987**, it is engaged in promoting, developing, and extending financial assistance for projects related to renewable energy and energy efficiency.

ENERGY CONSERVATION MEASURES

- The **Energy Conservation Act of 2001** is a legal framework regulating energy consumption, promoting energy efficiency, and conservation.
- Major provisions include designated consumers, standards and labeling of appliances, energy conservation building codes, creation of Bureau of Energy Efficiency, and the establishment of the Energy Conservation Fund.
- **Bureau of Energy Efficiency (BEE)** is a statutory agency under the Ministry of Power, focusing on developing programs for energy conservation.
  - **Star Rating Mobile App**

    This app, linked to the Standards and Labeling database, empowers consumers to:
    - **Compare** energy-efficient devices within a product category.
    - **Access** real-time user feedback.
    - **Make informed purchase decisions.**
- **Energy Conservation Building Code** (ECBC) sets minimum energy standards for commercial buildings, and ECO Niwas Samhita 2018 does the same for residential buildings.
- The **Stars and Labeling Program (BEE Star Label)** provides consumers with information on energy-saving potential, covering various appliances.
- **UJALA and SLNP** are initiatives by Energy Efficiency Services Limited (EESL) for LED distribution and streetlight replacement, contributing to significant greenhouse gas emission reduction.
- New energy performance standards for room air conditioners, including a mandatory 24°C default setting, aim to save electricity and reduce carbon intensity.
- **Indian Seasonal Energy Efficiency Ratio** (ISEER) is used for rating AC efficiency, considering season-wise temperature variations.
- **Smart Grid**
  - Utilizes **digital technology for two-way communication between utilities and consumers.**
  - **Components:** Smart grids consist of controls, computers, automation, and new technologies to respond digitally to changing electricity demand.
  - **National Smart Grid Mission (NSGM):** Launched in **2015**, NSGM plans and monitors the implementation of policies and programs related to smart grids.
  - **Benefits:** More efficient transmission, quicker restoration after disturbances, reduced peak

demand, and increased integration of large-scale renewable energy systems.

- **Sustainable Energy for All (SE4All):** Launched in 2011, SE4All is a multi-stakeholder partnership aiming to achieve three interlinked objectives by 2030: double the rate of improvement in energy efficiency, double the share of renewable energy in the energy mix, and universal access to modern energy services.
- **Energy Conservation (Amendment) Act, 2022**
  - Expands the scope of building codes to include measures for embedded carbon, net-zero emissions, and material efficiency.
  - Transitions Energy Conservation Building Codes to the Energy Conservation and Sustainability Building Code.
  - Makes ECO Niwas Samhita (Residential Energy Conservation Building Code) mandatory, as residential buildings account for 75% of electricity consumption in the sector.
- **National Mission for Enhanced Energy Efficiency (NMEEE) under NAPCC:** NMEEE is one of eight missions under the National Action Plan on Climate Change (NAPCC). It aims to boost energy efficiency by fostering favorable regulatory frameworks and sustainable business models in energy-intensive industries.

Key Initiatives Under NMEEE

Initiative	Description	Key Components/Benefits
Perform, Achieve, and Trade (PAT)	Market-based mechanism to improve cost-effectiveness of energy efficiency in energy-intensive industries.	❖ Units exceeding targets earn Energy Saving Certificates (ESCerts). ❖ ESCerts can be traded on power exchanges for compliance.
Market Transformation for Energy Efficiency (MTEE)	Aims to accelerate market adoption of energy-efficient products.	❖ **Bachat Lamp Yojana (BLY):** Promotes LED usage. ❖ **Super-Efficient Equipment Programme (SEEP):** Financial incentives for efficient appliances.
Energy Efficiency Financing Platform (EEFP)	Facilitates financing mechanisms for demand-side energy management programs.	❖ MoUs with financial institutions. ❖ Supports development of the energy efficiency market.
Framework for Energy Efficient Economic Development (FEEED)	Develops fiscal instruments to promote energy efficiency.	❖ **Partial Risk Guarantee Fund (PRGFEE):** Covers risks for banks lending to efficiency projects. ❖ **Venture Capital Fund (VCFEE):** Provides equity for projects in government buildings and municipalities.

❖ ❖ ❖

12 Key Government Schemes Related to Science & Technology in Rajasthan

SCIENCE AND TECHNOLOGY DEVELOPMENT IN RAJASTHAN

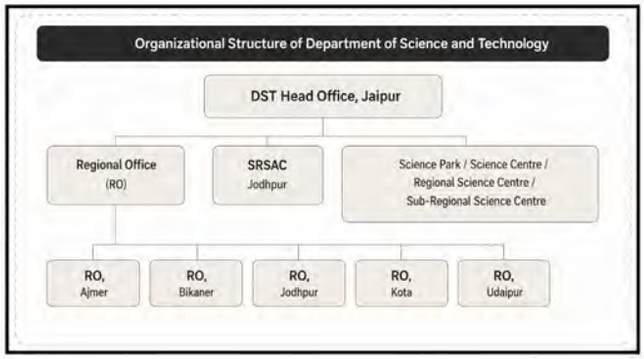
Development of Science and Technology in Rajasthan

The state of **Rajasthan** is currently moving towards becoming a modern and **progressive state** through a **scientific temper** and **technological innovation**. To bring **transparency and efficiency in governance**, the state government has prioritized cutting-edge technologies like **Artificial Intelligence (AI), Blockchain, and Data Analytics**, through which Rajasthan is emerging as an accountable and **technology-driven global model** of good governance. To strengthen this ecosystem, vital **institutions** like the **Department of Science and Technology (DST)**, iStart, and R-CAT, as well as visionary **policies** like the **Rajasthan AI and Machine Learning Policy-2026**, are actively functioning in the state. This **holistic approach** not only promotes **innovation** but is also fully committed to making the state a **leader** in the direction of the future **digital economy**. The Government of Rajasthan has taken special steps to promote a scientific temper and technological progress in the state.

Establishment of the Department

Department of Science and Technology

- **Establishment Year:** 1983
- **Name of the Department:** Department of Science & Technology
- **Objective:** To promote scientific research.
  - To popularize science among the general public.
  - To create awareness towards science.
  - To understand science on a practical basis rather than textbook knowledge.
- **Main Mission and Objectives of the Department**
  - **Policy Formulation and Capacity Building**
    - **S&T Policies:** To develop science and technology policies for the state.
    - **Institutional Strengthening:** To empower the capacities of human resources (scientists/ researchers) and institutions.
  - **Technology and Innovation**
    - To develop new technologies and expand them for the use of society.
    - To promote the innovative expansion of scientific methods.
  - **Social and International Role**
    - **Social Intervention:** To solve the problems of society through science.
    - **Collaboration and Partnership:** To act as a certified agency for cooperation and agreements at national and international levels.
  - **Resource Management:** To ensure the proper utilization of human, institutional, and financial resources so that the goal of sustainable development can be achieved.


Organizational Structure of Department of Science and Technology
DST Head Office, Jaipur
Regional Office (RO)
SRSAC Jodhpur
Science Park / Science Centre / Regional Science Centre / Sub-Regional Science Centre
RO, Ajmer
RO, Bikaner
RO, Jodhpur
RO, Kota
RO, Udaipur

Major Science Centers of the Department of Science and Technology (RAS 2016)

- **Major Science Centers:** Centers have been established at various levels in the state to make science accessible.
  - **Regional Science Center - Jaipur**
    - **Collaboration:** It has been established through the joint efforts of the Government of India's **National Council of Science Museums (NCSM)** and Rajasthan's **Department of Science and Technology**.
    - **Importance:** It is the premier center of the state, which is known for modern scientific exhibitions.
  - **Sub-Regional Science Center - Jodhpur**
    - **Function:** It is a major center for scientific activities and innovation at the regional level.

- **District Level Science Centers**
  - **Bikaner:** Science Center
  - **Udaipur:** Science Center
    - **Service Area:** This center covers **7 districts** of southern Rajasthan: Udaipur, Rajsamand, Bhilwara, Chittorgarh, Dungarpur, Banswara, and Pratapgarh.
  - **Kota:** Science Center
    - **Service Area:** It provides services to **7 districts** of Hadoti and its surroundings: Kota, Bundi, Baran, Jhalawar, Tonk, Karauli, and Sawai Madhopur.
- Science Parks
  - **Jhalawar:** Science Park
  - **Navalgarh (Jhunjhunu):** Science Park

KARYA (Knowledge Augmentation through Research in Young Aspirants)

- **Operator:** Department of Science and Technology (DST), Government of Rajasthan.
- **Duration: 8 weeks** during summer vacation.
- **Nature of the Scheme:** Meritorious student applicants studying in state government institutions get research experience in institutions of **national importance**.
- This scheme acts as a **'bridge'** to develop a research aptitude among college and university level students.
- **Major Affiliated Institutions:**
  - **IITs** (Indian Institutes of Technology)
  - **CSIR** (Council of Scientific and Industrial Research)
  - **ICMR** (Indian Council of Medical Research)
  - **DAE/DBT/DST** (Institutions of the Department of Atomic Energy, Biotechnology, and Science and Technology)
  - **ICAR** (Indian Council of Agricultural Research)
- **Benefit:** Students get the opportunity to work on short-term research projects, which enhances their scientific temper and career prospects.

Young Scientist Award - Rajasthan

- This award is given by the **Department of Science and Technology (DST)** of Rajasthan to encourage talented and energetic scientists and teachers of the state.
- **Eligibility and Criteria**
  - **Experience:** The applicant must have at least **2 years** of work experience as a teacher or scientist in any Higher Education Institution (HEI) or Research and Development (R&D) organization located in Rajasthan.
  - **Domain:** It is mandatory to be currently working in the field of Science and Technology (S&T) in Rajasthan.
  - **Age Limit:** The age of the applicant should not be more than **40 years**.
  - **Women Reservation:** Out of a total of 5 incentive awards, **02 awards** are reserved for female applicants.
- **Nomination Process**
  - **Who can nominate:** Nominations can only be sent through the Vice-Chancellor (VC) of universities, Principal of colleges, Director of institutions, Registrar, or Head of Department (HOD).
  - **Restriction: Self-nomination is not allowed.**
  - **Validity:** A nomination is valid for one year only. If selection does not take change, the nomination will not be 'carried forward' to the next year; however, **re-nomination** can be done.
- **Award Categories:** A certificate of appreciation is also presented along with the award-

Category	Award Amount
First Award	₹1.00 Lakh
Second Award	₹0.75 Lakh
Third Award	₹0.50 Lakh
Incentive Award (05)	₹0.10 Lakh (Each)

Department of Information Technology & Communication (DoIT&C)

- **Initial Establishment:** It was established as the 'Department of Computers' in the year 1987.
- **Name Change:** In the year 2000, its name was changed to 'Department of Information Technology & Communication' (DoIT&C).

Science & Technology Resource Centres (STRCs)

- The main objective of STRC (Science & Technology Resource Centres) is to deliver scientific knowledge to rural areas and solve local problems through technology.
- **Major Functions:**
  - To disseminate scientific knowledge in rural areas.
  - To promote need-based technologies.
  - To provide technical assistance at the local level.
- **8 STRCs of Rajasthan and their Implementation Agencies**

S.No.	Location of STRC (District)	Project Implementation Agency
1	Neemrana, Alwar	Krishi Prashikshan Kendra, PNB, Neemrana (Alwar)
2	Kanwarpura, Kota	Rajasthan Environment and Development Agency, Kota
3	Bahadurwas, Jhunjhunu	Samagra Vikas Sansthan, Jhunjhunu
4	Bambor, Jodhpur	Thar Voluntary Society, Jodhpur
5	Chandesara, Udaipur	Vigyan Samiti, Udaipur
6	Kumher, Bharatpur	LUPIN Human Welfare and Research Foundation, Bharatpur
7	Dadanpura, Jaipur	Kumarappa Gram Swaraj Sansthan, Jaipur
8	Kanpura (Srinagar), Ajmer*	Social Workers and Environment for Rural Development, Kanpura

INSTITUTIONAL DEVELOPMENT

Indian Council of Agricultural Research (ICAR)

- Indian Council of Agricultural Research is the **apex body** for guiding the agricultural system of the country.
- **Establishment Date:** 16 July, 1929
- **Original Name:** Imperial Council of Agricultural Research.
- **Nature:** It is an **autonomous body** under the 'Department of Agricultural Research and Education' of the Ministry of Agriculture (Government of India).
- **Role:** It is the **apex body** for coordinating and guiding the fields of horticulture, fisheries, animal sciences, and agricultural education.
- **Achievement:** ICAR has played a leading role in bringing about the **Green Revolution** in India and developing modern agricultural technology.
  - Following are the national-level research centers in **Rajasthan** under the Indian Council of Agricultural Research (ICAR)-

Central Arid Zone Research Institute (CAZRI)

- Operated under ICAR in Rajasthan, this is the most important national-level research center.
- **Full Name:** Central Arid Zone Research Institute
- **Headquarters:** Jodhpur (Rajasthan).
- **Collaboration:** It was established with the assistance of **Australia** and **UNESCO**.
- **Sequential Development of Establishment:** The establishment of CAZRI took place through a phased process-
  - **1952:** Establishment of 'Desert Afforestation Centre' (to check the expansion of the desert).
  - **1957:** Name changed to 'Desert Afforestation and Soil Conservation Centre'.
  - **1959:** It was given the status of a **full institute** under ICAR and named **'CAZRI'**, its present name.
- **Organizational Structure and Divisions:** The main office at Jodhpur has been divided into **6 divisions** for efficiency. Apart from this, its **5 regional research centers** have been established to solve the problems of different agro-climatic zones-
  - **Inside Rajasthan:** Jaisalmer, Bikaner, Pali.
  - **Outside Rajasthan:** Leh (Ladakh) and Bhuj (Gujarat).
- **Main Objectives**
  - To mitigate the process of desertification.
  - Scientific and sustainable management of natural resources in arid regions.
  - To develop new techniques of farming and animal husbandry in adverse climatic conditions.

Central Institute for Arid Horticulture (CIAH) (RAS 2016/2013)

- **Location:** Bichwal, **Bikaner**.
- **Establishment:** In the year 1993 as 'National Research Centre for Arid Horticulture'.
- **Name Change:** In September 2000, its name was changed to **CIAH** (Central Institute for Arid Horticulture).
- **Objective:** To develop new varieties of fruits and vegetables suitable for arid and semi-arid regions.

Directorate of Rapeseed-Mustard Research (DRMR) (RAS 2013)

- **Location:** Sewar, **Bharatpur**.
- **Establishment:** 20 October, 1993 as 'National Research Centre on Rapeseed-Mustard' (NRCRM).
- **Name Change:** In February 2009, it was made **Directorate of Rapeseed-Mustard Research**.
- **Main Function:** To conduct research on improved varieties and production technology of mustard.

National Research Centre on Seed Spices (NRCSS) (RAS 2018)

- **Location:** Dumara (Tabiji), **Ajmer**.
- **Establishment:** 20 April, 2000.
- **Objective:** To conduct research on improved seeds and their quality for spice crops (such as cumin, coriander, fennel, fenugreek).

Central Sheep and Wool Research Institute (CSWRI)

- **Location:** Avikanagar (Malpura), **Tonk**.
- **Establishment:** Year 1962.
- **Objective:** Improvement in wool production and its quality.
  - Research for breed improvement of sheep.
- **Regional Centre:** Under this, 'Arid Regional Campus' was established in **Bikaner** in the year 1974.

National Research Centre on Camel (NRCC) (RAS 2023)

- **Location:** Joheedbeed, **Bikaner**.
- **Establishment:** In the year 1984 as 'Directorate on Camel'.
- **Name Change:** On 20 September, 1995, its name was changed to **National Research Centre on Camel** (National Research Centre on Camel).
- **Main Function:** Research related to the conservation, breed improvement of camels, and their milk/ products.

Major Institutions Related to Promoting Science in the State

These institutions of Rajasthan are working to technologically empower the state and the country in the fields of agriculture, forestry, and electronics.

AGRICULTURE, HORTICULTURE AND FORESTRY

Rajasthan Agricultural Research Institute (RARI)

- **Location:** Durgapura, **Jaipur**.
- **Establishment:** It started in the year **1943** as the 'Agricultural Research Centre'.
- **Affiliation:** Currently, it is working under **Sri Karan Narendra Agriculture University, Jobner**.
- **Focus:** This institute is focused on advanced agricultural techniques and seed improvement in the state.
- **Sub-Stations Underneath:** To expand the work of the institute, it has three main centers:
  1. Tabiji (**Ajmer**)
  2. **Kotputli** (Jaipur)
  3. Diggi (**Tonk**)

Arid Forest Research Institute (AFRI)

- **Location: Jodhpur**.
- **Establishment:** On **30 June, 1987** by the 'Indian Council of Forestry Research and Education' (ICRE).
- **Naming:** It was officially given the name **'AFRI'**in the year **1988**.
- **Status:** It is a leading **national institute** in the field of environmental conservation and forestry in arid regions.
- **Domain:** This institute conducts research for the following regions:
  - Rajasthan
  - Gujarat
  - Dadra and Nagar Haveli
  - Daman and Diu
- **Main Objective:** To develop **forestry technologies** through scientific research in hot arid and semi-arid regions.
  - To increase the vegetative cover.
  - To conserve **biodiversity**.

Ber and Date Palm Research Centre

- **Location:** Bikaner.
- **Establishment:** Year 1971.
- **Major Achievement:** The 'Halawi' date palm variety developed by this centre is most famous for its quality and sweetness.
- **Focus:** This centre works specifically for the major horticulture crops of desert areas.

Central Wool Development Board (CWDB)

- **Location:** Jodhpur.
- **Establishment:** Year 1987.
- **Importance:** Since Jodhpur is the centre of Marwar and a large trade of wool takes place here, its headquarters has been kept here.
- **Function:** This board works to formulate policies for the development of the wool industry and the welfare of sheep rearers in the country.

Central Wool Analysis Laboratory (CWAL)

- **Location:** Bikaner.
- **Establishment:** Year 1965.
- **Function:** Scientific analysis of various wool samples is done here so that wool production can be done in accordance with international standards.
- **Role:** This laboratory is a technical centre for testing the quality of wool, strength of fibers, and fineness.

Krishi Vigyan Kendra (KVK)

- It is a strong network to deliver modern farming technologies to the farmers in Rajasthan.
- **Total Number:** About 42 Krishi Vigyan Kendras are established in Rajasthan.
- **Affiliation:** These centres work under the Indian Council of Agricultural Research (ICAR) and various agricultural universities of the state.

- **Main Function:** To conduct research in the field of agriculture, testing new technologies, and training farmers.

Major Agricultural Universities of Rajasthan

- **A total of 5 major universities are functioning in the state to promote agricultural education and research:**
  1. **Swami Keshwanand Rajasthan Agricultural University (SKRAU), Bikaner**
     - **Feature:** This is the **oldest** agricultural university in Rajasthan.
  2. **Maharana Pratap University of Agriculture and Technology (MPUAT), Udaipur**
  3. **Sri Karan Narendra Agriculture University (SKNAU), Jobner (Jaipur)**
  4. **Agriculture University (AU), Jodhpur**
  5. **Agriculture University (AU), Kota**

Central State Farm (Central State Farm)

- Sri Ganganagar district, due to its fertile land, is the hub of Asia's largest mechanized agricultural farms:

A. Suratgarh Central State Farm

- **Location:** Suratgarh, Sri Ganganagar.
- **Establishment: 15 August, 1956**.
- **Collaboration:** This was established with the financial and technical assistance of the **Soviet Union (Russia)**.
- **Importance:** This is India's **first** Central State Farm and Asia's **largest mechanized farm** (Mechanized Farm).
- **Additional Centre: Tharparkar Breeding Farm** (for breed improvement of cows) is also operated within the premises of this farm.

B. Jaitsar Central State Farm

- **Location:** Jaitsar, Sri Ganganagar.
- **Establishment:** Year **1964**.
- **Modern Development:** Currently, a **200 MW solar power plant** has been established here, which is an excellent example of the integration of agriculture and energy.

Major Agricultural Research Centers

Crop/Subject	Location	Special Details
Rice and Maize	Banswara	All India Coordinated Maize Improvement Project
Sorghum (Jowar)	Vallabhnagar (Udaipur)	Establishment: 1970
Isabgol (Psyllium)	Mandore (Jodhpur)	-
Pearl Millet (Bajra)	Jodhpur and Barmer	-
Cotton	Sri Ganganagar	-
Mustard (Rai)	Bharatpur	-
Plant Genetic Resources	Jodhpur	National Bureau of Plant Genetic Resources (1965)
Agricultural Marketing	Jaipur	Rajasthan Agricultural Marketing Research Institute
Floriculture Research	Mount Abu	Agro-Ecological Tourism and International Flower Center

ANIMAL HUSBANDRY AND DAIRY

Rajasthan University of Veterinary and Animal Sciences (RAJUVAS)

- **Location:** Bikaner.
- **Establishment:** Year 2010.
- **Feature:** It is a dedicated university in the field of veterinary science, education, and research in Rajasthan.
- **Note:** Under the bill passed by the Rajasthan Legislative Assembly in 2023, the second Rajasthan University of Veterinary and Animal Sciences will be established in **Jobner, Jaipur**. **(RAS 2023)**

Fisheries Survey and Research Centre

- **Location:** Udaipur.
- **Establishment:** Year 1958.
- **Importance:** Udaipur is called the 'City of Lakes', therefore, conducting research in the field of fisheries here is also geographically appropriate.

National Research Centre on Equines (NRCE)

- **Headquarters:** Hisar (Haryana).
- **Bikaner Sub-Campus:**
  - **Location:** Johadsbeed, **Bikaner**.
  - **Establishment:** Year 1989.
- **Feature:** Located in Bikaner, this centre specifically conducts research on the conservation and breeding of Marwari and Kathiawari breeds of horses.

- **Status:** This is the country's apex institution for the conservation of horses and other equine species (donkeys, mules) and research on their diseases.

Cattle Park and Animal Breeding Centre (Animal Husbandry Department)

- The main objective of these centres is to improve the breed of livestock in the state.
- **Kumher (Bharatpur) and Nagaur:** Cattle Breeding Farm (Cow-Bull Breeding Centre).
- **Ramsar (Ajmer):** Goat Breeding Farm.
  - **Feature:** Established in 1981-82 with the collaboration of **Switzerland**.
- **Fatehpur (Sikar):** Sheep Breeding Farm.
  - **Feature:**Established in 1973, this is the 'first centre of the state'
- **Alwar:** Pig Breeding Farm and Pig Development and Training Centre.
- **Ajmer:** State Poultry Training Institute.
- **Jamdoli (Jaipur):** Rajasthan State Animal Management and Animal Training Institute.

DEFENSE, ELECTRONICS AND ENGINEERING

Central Electronics Engineering Research Institute (CEERI)

- **Location:** Pilani, **Jhunjhunu**.
- **Establishment:** Year **1953**.
- It is a prestigious research institution of India in the field of electronics.
- **Affiliation:** It is one of the 38 major national laboratories of the country under the **Council of Scientific and Industrial Research (CSIR)**.
- **Importance:** This institute is world-renowned for research in modern fields such as vacuum microelectronics, cyber-physical systems, and smart sensors.

Defence Research Laboratory

- **Location:** Jodhpur.
- **Affiliation:** It is one of the 52 laboratories operating across the country under the **Defence Research and Development Organisation (DRDO)**.
- This institute is highly crucial for achieving self-reliance in the defence sector.
- **Function:** To conduct research on defence equipment, desert warfare skills, and military technologies.

Ceramic Electrical Research & Development Centre (CERDC)

- **Location:** Bikaner.
- **Development:** Established in **2007** under the name 'Ceramic Center'.
  - **2010:** The name was changed to **CERDC** (Ceramic Electrical Research & Development Centre).
- **Function:** To conduct technical research for the development of ceramic products and electrical equipment.

Biotechnology and Health Sciences

Desert Medical Research Centre (DMRC)

- **Location:** Jodhpur.
- **Establishment:** Year 1984.
- **Focus:** This institute focuses on specific health-related problems in desert areas.
- **Affiliation:** It is one of the 5 regional research centers in the country operating under the **Indian Council of Medical Research (ICMR)**.
- **Main Function:** To conduct research for the resolution of diseases and medical issues occurring in desert conditions.

Rajasthan State AYUSH Research Centre

- **Location:** Ajmer.
- **Announcement:** It was announced by Chief Minister Ashok Gehlot in **Budget 2021**.
- **Objective:** To promote scientific research and standardization in ancient Indian medical systems.
- **Significance:** This is a new initiative to promote Ayurveda, Yoga, Unani, Siddha, and Homeopathy (AYUSH).

Biotechnology

- **APJ Abdul Kalam Biotechnology Institute:** Chhitroli (Jaipur).
- **Tissue Culture Centre of Excellence:** It operates under the 'State Institute of Food Technology Entrepreneurship and Management' (SIFTEM).

Specific Research and Medical Centres

- **Advanced Centre for Medical Genetics (ACMG):** Jaipur (for research on genetic diseases).
- **Centre of Excellence for Sickle Cell Disease:** Udaipur.
- **Neuro Science Center:** Kota.

REMOTE SENSING AND SPACE APPLICATIONS

State Remote Sensing Application Centre (SRSAC) (RAS 2021)

- **Location:** Jodhpur.
- **Timeline of Development:**
  - **1979:** Established as 'Aerial Photo Interpretation Laboratory' under the Department of Agriculture.

- **1985:** Transferred to the Department of Science and Technology and renamed **SRSAC**.

- **Importance:** It is one of the 5 regional centres operated under the **National Natural Resources Management System**.
- **Main Function:** To analyze data received from satellites and suggest better management practices to the remote sensing centres of the state.
  - This centre assists in the management of resources through satellite technology and remote sensing.

State Remote Sensing Application Sub-Centre

- **Location:** Jaipur.
- The main centre is located in Jodhpur, while the sub-centre is located here.

INFORMATION TECHNOLOGY AND DIGITAL INFRASTRUCTURE

Rajasthan Center of Advanced Technology (R-CAT)

- **Launch:** August 2022 (Jaipur).
- **Registration:** Under the Societies Registration Act, 1958.
- **Guidance:** Department of Information Technology & Communication (DoIT&C).
- This is a premier institution providing industry-based skill training to the youth.
- **Expansion (Budget 2023-24):** Following the success in Jaipur, **5 new centers** are now being established in Ajmer, Bharatpur, Bikaner, Kota, and Udaipur.

Rajasthan State Data Center (RSDC)

- **Operation:** From 27 June 2011.
- **Feature (RSDC P-4):** It is located in Jaipur with a capacity of **600 racks**.
- **Record:** This is **India's largest Tier-4 government data center**.
- **Bhamashah State Data Center:** This is also located in Jaipur itself.
- Rajasthan's data management infrastructure is one of the strongest government data centers in the country.

Rajasthan Knowledge Corporation Limited (RKCL) (RAS 2023)

- **Establishment:** 25 April 2008.
- **Partnership:** It involves the Government of Rajasthan, MKCL (Pune), and major universities of the state (RU, MPUAT, VMOU).
- **Objective:** To promote **digital literacy** (such as the RS-CIT course) in the state.

Rajcomp Info Services Limited (RISL)

- **Establishment:** 27 October 2010 (Former name: RajComp).
- **Role:** It is the **nodal agency** of the state that implements the 'National E-Governance Plan' (NeGP).

IT / Technology Parks and Electronic Complexes of Rajasthan

Project / Park	Location	Special Details
Biotechnology Park (IT Park)	Sitapura (Jaipur)	For biotechnology and IT development
IT/Industrial Park	Chopanki (Bhiwadi), Khairthal–Tijara	Industrial and IT activities
Cyber Park	Jodhpur	Developed by RIICO
Software Technology Park	Kanakpura (Jaipur)	For IT/Software industry
Electronic Hardware Technology Park	Kukas (Jaipur)	For hardware manufacturing
Electronics Complex	Kota	Regional electronics development

Advanced Technology and Innovation Centres

- **Central Electronics Engineering Research Institute:** Pilani (Jhunjhunu - Established 1953) **(RAS 2013)**
- **Rajasthan Application Development Centre (Raj. CAD):** Training is provided here in technologies like JAVA, RDBMS, mobile app development, and PHP.
- **Security Operation Centre:** Jhalana, Jaipur (for cyber security).
- **Blockchain Centre of Excellence:** Jaipur (an MoU has been signed with IIT Kanpur for this).
- **Amrit Global Technology & Application Center of Excellence:** Jaipur.
- **Generative AI Centre:** It has been established in IIT Jodhpur in collaboration with 'India AI' and 'Meta'.
- **Rajasthan Institute of Advanced Technology:** Bikaner
- **IT Park:** Ajmer

Rajasthan Patent Information Centre (PIC)

- The Patent Information Centre acts as a bridge between innovation and legal protection in the state.
- **Establishment and Partnership:**

- **Establishment Year:** 1998
- **Joint Initiative:** This centre is operated in collaboration with the following institutions:
  - **TIFAC:** Technology Information, Forecasting and Assessment Council (Government of India).
  - **DST:** Department of Science and Technology (Government of India and Government of Rajasthan).

❖ **Main Objective:** Its primary goal is to bring Patent Search and application facilities to the doorsteps of innovators, researchers, scientists, and entrepreneurs for the protection of their intellectual work.

❖ **Major Services Provided by PIC:** The centre provides assistance on every aspect of intellectual property—
- **Registration Assistance:** Helping in the application of patents, copyrights, designs, and GI (Geographical Indications).
- **Search and Analysis:** Providing patent search facilities and technical analysis of patent information.
- **Education and Training:** Awareness workshops and seminars on IPR (Intellectual Property Rights) matters.

❖ **Intellectual Property Facilitation Centre (IPFC):** A special unit has been established to strengthen the MSME sector—
- **Goal:** To provide intellectual property-related facilities to the Micro, Small, and Medium Enterprises (MSMEs) of Rajasthan.
- **Location:** This centre has been established within the premises of RajCOST/DST (Department of Science and Technology), Government of Rajasthan.
- **Target Group:** Small and Medium Enterprises (SMEs/MSMEs)
- Universities and Educational Institutions

❖ Individual Inventors
- **Nature of Assistance:**
- **Financial Assistance:** Financial support for filing and prosecuting patents in the Indian Patent Office.

❖ **Consultancy Support:** Expert advice to resolve legal and technical complexities.

Rajasthan State Intellectual Property Rights (IPR) Policy 2021–2026

❖ This policy is designed to ensure legal protection and commercial benefits for innovations.

❖ **Nodal Agency:** RAJCOST (Rajasthan Council of Science and Technology).
- **Main Goal:** To give global recognition to the innovations of Rajasthan.

MAJOR POLICIES RELATED TO SCIENCE AND TECHNOLOGY

Rajasthan AVGC-XR Policy, 2024

❖ This policy is designed to make Rajasthan a **global hub** in the fields of Animation, Visual Effects, Gaming, Comics, and Extended Reality.

❖ **Date of Implementation:** 9 December, 2024

❖ **Effective Period:** Until 31 March, 2029

❖ **Main Vision:** To make Rajasthan a hub for the 'Digital Creative Industry' through innovation, investment, and employment.

❖ **Administrative and Regulatory Reforms**
- **Single Window Portal:** Making all clearances and incentives available to investors at a single point.
- **Dedicated AVGC-XR Cell:** Setting up a special nodal cell for effective implementation of the policy and assisting investors.
- **Ease of Doing Business:** Making procedures simple, transparent, and swift.

❖ **Cultural and Research Focus**
- **Cultural Promotion:** Special incentives for creating digital content (animation/gaming) based on Rajasthani folk culture, history, and folk songs.
- **Intellectual Property (IP) Creation:** Supporting original content and innovation laboratories.
- **Streaming Platform Collaboration:** Strategic partnership with media and OTT platforms.

Major Pillars and Provisions

Financial Incentives	Infrastructure Development	Skill Development and Employment
❖ **Production Cost Reimbursement:** Financial assistance of **up to 30%** on production costs for eligible projects. ❖ **Startup Support:** Special financial assistance for new entrepreneurs for innovation and business expansion.	❖ **Atal Innovation Studio:** Ensuring the availability of high-level technological resources and equipment. ❖ **Accelerator and Incubation:** Setting up dedicated centers for the development of startups. ❖ **Sandbox:** Creation of an 'AVGC-XR Sandbox' for testing new ideas.	❖ **Industry-Oriented Workforce:** Conducting specialized courses and training programs in collaboration with universities and private institutions. ❖ **Employment Generation:** Providing global-level employment opportunities to youth at the local level.

Rajasthan AI / ML Policy 2026

- This policy has been implemented by the Government of Rajasthan to bring the power of Artificial Intelligence (AI) and Machine Learning (ML) into the mainstream of governance and development.
- **Launch Date:** 6 January, 2026.
- **Occasion:** Rajasthan Regional AI Impact Conference, Jaipur.
- **Vision:** Achieving the goals of 'Viksit Rajasthan @2047' and ensuring inclusive development.
- **Strategic Goals of the Policy:**
  - **Responsible AI:** Ensuring the deployment of AI in a safe, ethical, and responsible manner.
  - **Institutional Capacity:** Preparing the technical capacity of government departments and private sector entities to be future-ready.
  - **Employment Generation:** Creating millions of new technical job opportunities in the fields of AI and Data Science.
- **Key Pillars of the Policy:** This policy focuses on the following areas to establish the state at a global level in the field of AI:
  - **Robust Digital Infrastructure:** Rajasthan already has a strong foundation, which will be utilized for AI.
    - **Tier-4 Government Data Center:** India's safest and largest data center.
    - **Comprehensive Connectivity:** Extending internet access to villages through 'BharatNet'.
    - **E-Mitra Network:** For delivering AI-based services to the last mile.
  - **Talent and Innovation:**
    - **Academic Strength:** A network of more than 80 universities and national institutions (IIT, IIM, MNIT).
    - **Role of R-CAT:** For advanced skill development and preparing AI experts.
  - **Improvement in Governance:**
    - **Transparency:** Data-driven decision-making in government services.
    - **Modernization:** Making public service delivery faster and more accurate.
    - **Inclusivity:** Equal access to the benefits of AI in both urban and rural areas.

Rajasthan Biotechnology Policy 2015

- This policy is designed to accelerate research, innovation, and industrial development in the field of biotechnology in the state.

Main Details and Objectives

- **Nodal Agency:** Department of Science and Technology (DST), Government of Rajasthan.
- **Primary Goal:** To create a robust ecosystem for biotechnology research, development, and commercialization in Rajasthan.
- **Regulatory and Institutional Framework:** A three-tier administrative system has been set up for the effective implementation of the policy:
  - **Rajasthan Biotechnology Council (RBC):** This is the state's apex advisory body under the chairmanship of the Chief Minister.
  - **Rajasthan State Biotechnology Mission (RSBTM):** It monitors the implementation of policies under the chairmanship of the Chief Secretary.
  - **Biotechnology Development, Regulatory and Testing Authority (RBRA):** This is an independent single-window authority that simplifies the processes of approvals and testing.
  - **Digital Control:** The entire regulatory system has been made transparent through a 'web-based online system'.
  - **Bio E-Commerce Agency:** To promote the marketing and trade of products.
- **Key Provisions and Financial Assistance:** Attractive financial provisions have been made under the policy to encourage industries and researchers:
  - **A. SBIRI Co-financing:** Support to industries in collaboration with the Government of India's 'Small Business Innovation Research Initiative' (SBIRI)
    - **Projects < ₹1 crore:** Assistance up to ₹25 lakh.
    - **Projects > ₹1 crore:** Assistance up to ₹50 lakh.
  - **B. Collaborative Research Grant:** Financial assistance by the state government for biotech projects of public importance:
    - **Small Projects (< ₹1 crore):** Maximum up to ₹25 lakh.
    - **Large Projects (> ₹1 crore):** Maximum up to ₹50 lakh.
  - **C. IPR (Intellectual Property Rights) Support:** Patent assistance to protect innovations:
    - **Reimbursement:** Up to 50% of the patent and IPR registration cost.
    - **Maximum Limit:** Up to ₹3 lakh.
    - **Conditions:** There will be no revenue sharing with the state government.
    - This benefit can be availed by an institution or individual for only one product/process.

13 Contribution of Indians in Science & Technology

THE CONTRIBUTIONS OF INDIAN SCIENTISTS

1. Srinivasa Ramanujan Aiyangar (1887–1920)

- **Field:** Mathematics
- **Contributions:**
  - Ramanujan is celebrated for his pioneering contributions in the fields of **mathematical analysis, number theory, and infinite series.**
  - Despite lacking formal training, his intuition and originality led him to derive over 3,000 mathematical results, including properties of highly composite numbers, the **Ramanujan prime, the Ramanujan theta function, and partition formulae.**
  - In 1911, he published in the same journal a brilliant research paper on **Bernoulli** numbers. This got him recognition, and he became well known as a mathematical genius.

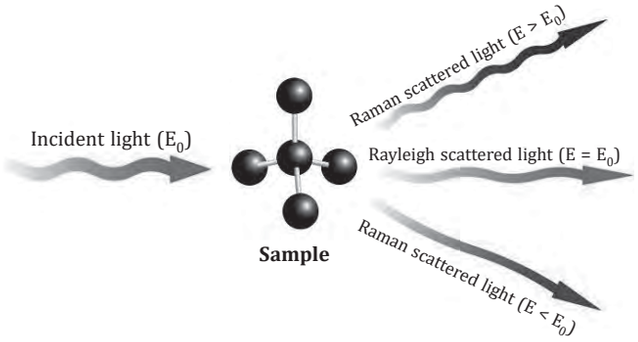
2. Chandrasekhara Venkata Raman (1888–1971) (RAS 2013)

- **Field:** Physics
- **Contributions:** He is best known for his work on the **scattering of light** and the discovery of the **Raman effect,** which is the change in the wavelength of light that occurs when a light beam is deflected by molecules. National Science Day(28 February) is celebrated every year to commemorate the discovery of the Raman Effect .

Raman Effect

When light hits a molecule, most of it just bounces back in the same way (this is called **elastic scattering**). But a small part of the light gets scattered in a different direction, with its energy slightly changed. This happens because the light interacts with the vibrations of the molecules in the substance, and that changes the color (or wavelength) of the light.

Rayleigh scattering is elastic, meaning that the scattered light has the same energy and wavelength as the incident light, while **Raman scattering** is inelastic, meaning that the scattered light has a different energy and wavelength than the incident light.



This change in light's energy is what we call the **Raman Effect**. It's used in various scientific fields, like studying the composition of materials **(Raman Spectroscopy)**.

3. Jagdish Chandra Bose (1858–1937)

- **Field:** Physics, Biophysics, and Botany
- **Contributions:**
  - In recognition of his work on **"The Electromagnetic Radiation and Polarisation of Electric Rays,"** he was knighted in 1917 and became a Fellow of the Royal Society of London in 1920. This distinguished him as the first Indian physicist to achieve this honour in the field of physics.
  - Bose is credited with making significant contributions to the field of **radio and microwave optics.** He pioneered the investigation of **radio and microwave optics,** and he significantly contributed to plant science by experimenting with plant stimuli.

4. Homi Jahangir Bhabha (1909–1966)

- **Field:** Nuclear Physics
- **Contributions:** Bhabha is known as the **father of the Indian nuclear India's three-stage nuclear power programme was formulated by him.** He was the founding director of the **Tata Institute of Fundamental Research and the Trombay Atomic Energy Establishment (now Bhabha Atomic Research Centre).**

5. Vikram Ambalal Sarabhai (1919–1971)

- **Field:** Space Science
- **Contributions:**
  - Dr. Vikram Ambalal Sarabhai, a prominent figure in modern India, was the founder of the Indian Space Research Organisation (ISRO), and he also spearheaded the launch of India's inaugural satellite, Aryabhatta. (RAS 2013)

- Under the **mentorship of Dr. C.V. Raman**, he delved into the study of **cosmic rays,** culminating in a Ph.D. from Cambridge University. His **research on cosmic rays** revealed their origin as energetic particles from outer space, undergoing alterations influenced by the sun, the Earth's atmosphere, and magnetic forces during their journey to Earth.

6. Satyendra Nath Bose (1894–1974)

- **Field:** Physics.
- **Contributions:**
  - He was a renowned **Indian physicist** known for his work in **quantum mechanics** in the early 1920s. His most significant contribution was the development of **Bose-Einstein statistics** and the theory of the **Bose-Einstein condensate,** a state of matter for a **dilute gas of bosons** cooled to temperatures very close to **absolute zero.**
  - This work laid the foundation for the discovery of the Bose-Einstein condensate phenomenon, a pivotal concept in **quantum physics.** Bose's collaboration with Albert Einstein led to the development of Bose-Einstein statistics, which describe the statistical distribution of identical particles with integer spin, known as bosons, named in his honour.

Bose-Einstein Condensate (BEC)

Bose-Einstein Condensate (BEC) is a unique state of matter that forms when a group of atoms is cooled to temperatures near absolute zero (0 Kelvin or -273.15°C). At such extremely low temperatures, the atoms slow down so much that they begin to behave as a single quantum entity rather than as individual particles. In this state, particles, specifically bosons, occupy the same quantum state, essentially merging into one "super-atom."

BEC is known as 5th state of matter.

- **Near Absolute Zero:** Atoms are cooled to almost no motion.
- **Bosons:** Particles that can share quantum states.
- **Quantum Behavior:** Atoms behave as one large quantum entity.

Bose-Einstein Statistics

Bose-Einstein statistics describe the behavior of **bosons**—particles that can occupy the same quantum state without exclusion, unlike fermions (which follow the Pauli Exclusion Principle). These statistics explain how groups of indistinguishable particles (bosons) distribute themselves among various energy levels, particularly at very low temperatures.

- A key result is that, at extremely low temperatures, bosons tend to cluster in the same energy state, leading to phenomena like the **Bose-Einstein Condensate**. This statistical model was developed by **Satyendra Nath Bose** and further expanded by **Albert Einstein**.

7. Subrahmanyan Chandrasekhar (1910–1995)

- **Field:** Astrophysics
- **Contributions:** Subrahmanyan Chandrasekhar was a distinguished astrophysicist whose contributions significantly advanced the understanding of **stellar evolution.** He is best known for his theoretical work on the physical processes important to the structure and evolution of stars, including his formulation of the **Chandrasekhar limit.** For his profound contributions to the field of astrophysics, **Chandrasekhar was awarded the Nobel Prize in Physics in 1983,** sharing it with William A. Fowler.

Chandrasekhar Limit

The **Chandrasekhar limit** is the maximum mass a white dwarf star can have, about **1.4 times the mass of the Sun**. If a white dwarf's mass exceeds this limit, it cannot support itself through electron degeneracy pressure, and it collapses into a **neutron star** or a **black hole**. This concept is crucial in determining the fate of dying stars.

8. Har Gobind Khorana (1922–2011)

- **Field:** Biochemistry
- **Contributions:**
  - Har Gobind Khorana was a **Nobel Prize-winning biochemist** of Indian origin, celebrated for his groundbreaking research in **genetics.**
  - His most notable contribution was elucidating the role of **nucleotides** in protein synthesis, which was pivotal in understanding how genetic information is translated into proteins. Khorana's work on the synthesis of **oligonucleotides,** compounds that form the structure of DNA, was instrumental in the development of biotechnology.
  - For his significant contributions to the field of molecular biology, he was awarded the **Nobel Prize in Physiology or Medicine in 1968,** alongside Robert W. Holley and Marshall W. Nirenberg.

Oligonucleotides

Oligonucleotides are short sequences of nucleotides (the building blocks of DNA and RNA). Typically, they consist of about 20 to 25 nucleotides and are used in various biological and medical applications, such as genetic testing, research, and therapies.

They can be synthesised in the lab and used as primers in **PCR (Polymerase Chain Reaction)**, probes in **gene sequencing**, or even as therapeutic agents in **gene editing** technologies like CRISPR.

- **Short DNA/RNA sequences:** About 20-25 nucleotides long.
- **Applications:** Used in diagnostics, gene synthesis, and therapies.

9. M. Visvesvaraya (1861–1962)

- **Field:** Civil Engineering
- **Contributions:**
  - M. Visvesvaraya was an eminent Indian engineer and statesman, widely regarded for his contributions in the fields of **civil engineering** and public works.
  - His most notable work includes the **design and construction of the Krishna Raj Sagara Dam on Kaveri river in Mysore,** which played a pivotal role in transforming the region's irrigation system and agriculture.

10. Tessy Thomas (1963)

- **Field:** Missile Technology
- **Contributions:**
  - She is often referred to as the **"Missile Woman of India"** and has made significant contributions to India's defence research and development.
  - She is the first woman scientist to head a missile project in India, notably the **Agni-IV** missile project, a **long-range nuclear-capable missile.**

11. Shanti Swaroop Bhatnagar (1894–1955)

- **Field:** Chemistry
- **Contributions:**
  - Shanti Swaroop Bhatnagar was a renowned Indian scientist and a pioneer in the field of **chemical research in India.**
  - He is best known for his significant contributions to **industrial chemistry and for establishing the Council of Scientific and Industrial Research (CSIR)** in India, serving as its first Director-General. Bhatnagar's work in the realm of chemical sciences led to the discovery of the **Bhatnagar-Mathur Magnetic Interference Balance,** a key instrument in scientific research.

12. Salim Ali (1896–1987)

- **Field:** Ornithology
- **Contributions:** Salim Ali, popularly known as the **"Birdman of India,"** was a pioneering Indian **ornithologist and naturalist.** He is best known for his systematic survey of the birds of India and several bird books, including the highly influential **"The Book of Indian Birds."**

13. M. S. Swaminathan (1925)

- **Field:** Agriculture
- **Contributions:**
  - He is a renowned **Indian geneticist** and **international administrator,** celebrated for his leading role in **India's Green Revolution,** a movement that transformed agriculture in India and helped alleviate hunger and poverty in the 1960s and 1970s.
  - His development and promotion of **high-yielding varieties** of wheat and rice significantly increased food production in India, making the country self-sufficient in cereals and preventing widespread famine.
  - The Green Revolution in India, championed by M. S. Swaminathan, introduced high-yielding variety (HYV) seeds to boost food grain production, particularly wheat and rice. HYV wheat seeds were sourced from Mexico, developed by Norman Borlaug, while rice seeds (e.g., IR-8) came from the International Rice Research Institute (IRRI) in the Philippines.
  - These semi-dwarf varieties were bred using plant breeding and genetic modification techniques, making them resistant to lodging and highly responsive to fertilizers and irrigation. The adoption of modern pesticides and irrigation systems further enhanced productivity.

14. Meghnad Saha (1893–1956)

- **Field:** Physics, Astrophysics
- **Contributions:**
  - Meghnad Saha was an eminent **Indian astrophysicist** best known for his development of the **Saha Equation,** a fundamental formula in astrophysics that describes the **physical and chemical conditions** of stars.
  - This equation, crucial in the study of stellar atmospheres, helps in determining the temperature and ionization state of various elements in stars.

Saha Equation

The **Saha Equation** is a mathematical formula used in astrophysics to describe the ionization equilibrium of gases in stars. It relates the ionization states of atoms to the temperature and pressure of the gas.

- **Ionization:** The process by which an atom loses or gains electrons to become an ion.
- **Applications:** Helps in understanding the spectral lines of stars, predicting the population of ionized atoms, and analyzing stellar atmospheres.
- **Formula:** The equation expresses the ratio of the number of ions to neutral atoms in a gas as a function of temperature and electron pressure.

15. Prasanta Chandra Mahalanobis (1893–1972)

- **Field:** Statistics
- **Contributions:**
  - He was a renowned **Indian statistician and scientist,** best known for his pioneering work in statistics. He is credited with the development of the **Mahalanobis distance,** a statistical measure used to analyze the divergence between different data sets.
  - Mahalanobis also played a key role in the formulation of **India's second five-year plan,** which focused on industrialization and economic development.

16. Dr. Dilip Mahalanabis (1934-2022)

- **Field:** Medication
- **Contributions:** He invented the Oral Rehydration Solution (ORS) while working in refugee camps during the 1971 Bangladesh Liberation war. The Lancet called ORS "the most important medical discovery of the 20th century".

17. Upendranath Brahmachari (1873-1946)

- **Field:** Physiology or medicine
- **Contributions:** He synthesized **urea-stibamine** in 1922 and determined that it was an effective treatment for **kala-azar.**

18. Narinder Singh Kapany (1926-2020)

- **Field:** Physics
- **Contributions:** He was an Indian-American physicist best known for his work on fiber optics. Kapany is a pioneer in the field of fiber optics, and known for coining and popularizing the term.

NOBEL PRIZES

Nobel Prize Winners: 2025

Category	Laureate(s)	Reason for Award
Physics	John M. Martinis; Michel H. Devoret; John Clarke	"For the discovery of macroscopic quantum mechanical tunnelling and energy quantisation in an electric circuit."
Chemistry	Susumu Kitagawa; Richard Robson; Omar M. Yaghi	"For the development of metal-organic frameworks" — molecular constructions with large internal spaces allowing gas/chemical flow, with applications such as water harvesting, carbon dioxide capture, toxic gas storage or catalysis.
Physiology or Medicine	Mary E. Brunkow; Fred Ramsdell; Shimon Sakaguchi	"For their discoveries concerning peripheral immune tolerance" — understanding how the immune system is kept in check so it does not attack the body's own tissues.
Literature	László Krasznahorkai	"For his compelling and visionary oeuvre that, in the midst of apocalyptic terror, reaffirms the power of art."
Peace	María Corina Machado	"For her tireless work promoting democratic rights for the people of Venezuela and for her struggle to achieve a just and peaceful transition from dictatorship to democracy."
Economic Sciences	Joel Mokyr; Philippe Aghion; Peter Howitt	"For having identified the prerequisites for sustained growth through technological progress" and "for the theory of sustained growth through creative destruction".

Indian Nobel Prize Winners

Name	Year	Category	Field of Contribution
C. V. Raman	1930	Physics	Raman Effect in light scattering.
Har Gobind Khorana	1968	Physiology or Medicine	Work on the genetic code and protein synthesis.
S. Chandrasekhar	1983	Physics	Research on the structure and evolution of stars.
Venkatraman Ramakrishnan	2009	Chemistry	Studies of the structure and function of the ribosome.

Note: This table only mentions Indian Nobel Laureates in the field of Science and Technology.

Other Indian Nobel Laureates include: **Rabindranath Tagore, Mother Teresa, Amartya Sen and Kailash Satyarthi.**

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